NOTES ON

BUILDING AND ROAD-MAKING,

WITH

RULES FOR ESTIMATING REPAIRS

TO

TANKS AND CHANNELS;

COMPILED FOR THE USE OF

SURVEYORS AND OVERSEERS

IN THE DEPARTMENT OF PUBLIC WORKS;

WITH AN APPENDIX

CONTAINING BUILDING DATA AND OTHER TABLES.

Illustrated by Thirty-seven Plates.

EIGHTH EDITION,
Carefully revised and Enlarged.

MADRAS:
HIGGINBOTHAM AND CO.
By Appointment in India to His Royal Highness the Prince of Wales.
1890.
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LIST OF SURVEYING AND OTHER INSTRUMENTS

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School pocket leather case, containing 5 inch pair of pull-off brass compasses, pen and pencil legs,		

[...]uation see end of Book.)

PUBLISHERS' PREFACE,

THE SEVENTH EDITION.

In bringing out a new edition of this long established Text-Book on "Building and Road-making," the Publishers have to state that the previous edition was exhausted in 1870. Ever since, numerous applications from the three Presidencies have been received for copies—a proof of the repute the work is still held in by the members of the Department of Public Works. The delay, however, in issuing this edition was owing to the difficulty experienced in securing the services of an editor to revise and otherwise improve its usefulness.

The original form of the work has in every respect been retained. In some few instances the subjects, which required to be re-written and re-arranged, have been carefully attended to. The editor has, moreover, contributed some additional matter under the head of Asphalte, Brick-work, Concrete, Hip Roof, &c., &c., and two new plates marked A and B have been added.

Much matter in the Appendix of the old edition having been found of no material value now, has been thrown out, and other information of a useful and practical character has been introduced in its place, and the Table of Data has been considerably enlarged and improved and made specially useful to Builders and Contractors, &c.

Colonel R. H. Sankey's "Tables of Scantling of Timber for Roofs," is, with permission, inserted in this edition.

In its improved form, the Publishers trust that it will command that extensive sale which was accorded to the previous impressions.

August 1875. H. & CO.

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NOTES

ON

BUILDING AND ROAD-MAKING.

CHAPTER I.

SURVEYING AND LEVELLING.

ESTIMATES for making new roads (and for repairing old ones, when deviations from the line are to be made) should always be accompanied by surveys, showing the existing track and the proposed deviations, and also the ground on each side to a distance of a few hundred feet. Sketches of the country should be forwarded with all projects of importance for improving and extending irrigation; and when new channels are to be cut, or old ones cleared out, a section of the ground, or bed of the channel, is necessary to allow of the estimate being prepared with correctness. The sheets of the Trigonometrical Survey, which are engraved on a scale of four miles to an inch, will be found very useful, to show the lay of the country and positions of places; but, surveys on a scale of from four to eight inches to a mile will be required, to show all the water courses and bridges on roads, and to illustrate reports on the irrigation of particular parts of a district. It is not intended here, to give an account of all the operations of an extensive survey, but merely to describe the method of making those surveys and sketches which are called for from overseers, and the uses and adjustments of the instruments, with which they are usually furnished.

SECTION I.—Surveying.

The Pocket Compass.—The pocket compass, which is the instrument usually employed in making the surveys, consists of a small brass box, containing a card, which, being attached to a magnetic needle, moves, as *it* moves, round the agate centre, on which it is suspended. The circumference of the card is usually divided to 15′ of a degree, but it is doubtful whether an angle can be measured by it even to that degree of accuracy. There is a prism fixed to the side, which the observer looks through in observing with the instrument. The perpendicular thread of the sight-vane, and the divisions on the card appear *together* on looking through the prism; and the division with which the thread coincides, when the needle is at rest, is the magnetic azimuth of whatever object the thread may bisect. The prism is mounted with a hinge joint, by which it can be turned over to the side of the compass box, that being its position when put into the case. The sight-vane has a fine thread stretched along its opening, in the direction of its length, which is brought to bisect any object, by turning the box round horizontally; the vane also turns upon a hinge joint, and can be laid flat upon the box, for the convenience of carriage. A mirror is made to slide on or

off the sight-vane ; and it may be reversed at pleasure, that is, turned face downwards : it can also be inclined at any angle, by means of its joint ; and it will remain stationary on any part of the vane, by the friction of its sides. Its use is to reflect the image of an object to the eye of the observer, when the object is much above or below the horizontal plane. When the instrument is employed in observing the azimuth of the sun, one of the colored glasses must be interposed ; the joint upon which they act allowing them to be turned down over the sloping side of the prism-box. There is a spring at the side, which, being pressed by the finger at the time of observation, and then released, checks the vibrations of the card, and brings it more speedily to rest. A stop is likewise fixed at the other side of the box, by which the needle may be thrown off its centre ; which should always be done when the instrument is not in use, as the constant playing of the needle would wear away the point on which it is balanced, and upon the fineness of the point much of the accuracy of the instrument depends.* A cover is adapted to the box, and the whole is packed in a leather case, which may be carried in the pocket without inconvenience.

The method of using this instrument is very simple. First, raise the prism in its socket, until distinct vision of the divisions of the card is obtained, and standing at the place where the angles are to be taken, hold the instrument to the eye, and looking through the slit, turn round till the thread in the sight-vane bisects one of the objects whose azimuth, or angular distance from any other object, is required; then, by touching the spring, bring the needle to rest, and the division on the card which coincides with the thread on the vane, will be the azimuth or bearing of the object from the north point of the magnetic meridian. Then turn to any other object and repeat the operation, the difference between the bearing of this object and that of the former, will be the angular distance of the objects in question. The compass card is usually numbered from 0 to 360 degrees, which is much more convenient than when it is divided into twice 180 degrees. A tripod stand is often used, on which the instrument is placed when observing, instead of holding it in the hand.

The Perambulator.—For measuring distances, the 100 feet chain, the twelve feet rod and the perambulator are employed. The 8 mile perambulator, in use in the Madras Presidency, consists of a wheel, 20 feet in circumference, having a brass plate, 7 inches in diameter, on each side of its centre for connecting the spokes. On one side, the plate is graduated in feet and inches from 1 to 20 feet, in three circles, one within the other, each circle containing $6\frac{2}{3}$ feet. An axle passes through the centre of these plates, to which is attached an endless screw, playing in the teeth of two circular brass plates $8\frac{1}{2}$ inches in diameter, suspended from the axle, one plate having 66, and the other 64 teeth. The front plate is graduated to 220 yards, and the back plate to furlongs and miles, which are read off through the openings in the front plate, one index being turned down on the plate to denote the yards, and the other index with adjusting weight denoting the feet and inches on the plate attached to the wheel. The axle is furnished at both ends with a revolving wooden handle.

* This remark also applies to the spirit levels and other instruments of which the compass forms part.

Fig. I.

Fig. 2.

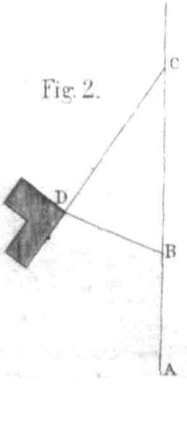
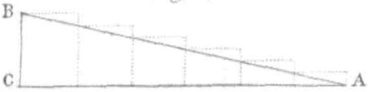


Fig. 3.



Surveying with the Chain only.—This operation is confined to one and the simplest figure, namely, the triangle; for, of all plane geometrical figures, it is the only one of which the form cannot be altered, if the sides remain constant (Euclid vii, 1.) The surface to be measured is, therefore, divided into a series of imaginary triangles which are to be as large, with reference to the whole surface to be measured, as is consistent with the nature of the ground. The sides of these triangles are first measured, and, as a necessary check on this part of the work, a straight line is in addition measured from one of the vertices to a point in or near the middle of the opposite side or base line. This fourth line is called a tie-line or proof-line, and is intended to prove the accuracy of the measurement of the sides when the triangle is plotted. The sides of the larger triangles are to pass as close as possible to the external boundaries to be surveyed, and they, moreover, should be made to approach, as nearly as practicable, to the form of the equilateral, avoiding with care very acute or obtuse angles. Within the larger triangles, as many tie-lines and smaller triangles are to be measured as may be necessary to determine the position of all objects embraced in the survey. If the sides of these secondary triangles be in any case so distant from the objects whose positions are to be determined, as to require a length of offset greater than about 100 feet, it then becomes advisable to construct, either on the whole, or a part of the side of the triangle as a base, a smaller offset triangle with the sides so disposed that they shall either embrace, or pass very near to, the objects to be measured by their intervention. The vertices of the triangles, as well as the points of intersection *of all straight lines, are always points measured to or from;* they are called station points or stations, and the lines connecting these points, are called station lines, thereby distinguishing them from the simple offset lines.

It is customary, before commencing any measurement, to walk over the ground for the purpose of obtaining a general knowledge of the surface, and of the relative positions of the most conspicuous objects. The acquisition of this knowledge, is much assisted by an eye-sketch drawn with rapidity, to no scale, and showing some of the principal objects, &c., and giving a general resemblance to a plan of the ground.

Let the line AB be the *base-line* in the diagram Fig. 1, Plate A, and the principal triangles, constructed upon this base are A *d b*, *b f c*, B *g a*, A *i a;* the lines connecting the vertices, or sides of these triangles, are those marked *e f* and *h g*, which form two other triangles, viz., *e f b*, and *a h g;* these connecting lines, in plotting, will be a check on the accuracy of the lengths of the sides of the triangles A *d b*, *e b f*, *b f c*, B *g a*, *g h a*, A *i a*, and are called tie-lines. For the more remote parts of the survey, other triangles are formed upon the sides of the triangles already constructed, as *g n m*, *n o m*, *o h m*, *&c.*, and when any part of the boundary of the survey is within ordinary distance of any of the lines above described, offsets are taken; these offsets are represented upon the diagram by short dotted lines.

For the better fixing of the several points, it is advisable, to measure lines from the vertices of some of the triangles to given points on their opposite sides, and to prolong those lines so as to intersect the

sides of the adjacent triangle; thus, when the sides of the triangles B *g a*, A *i a*, *g h a* are measured, the line *h* B, be also measured, noting the distance where it crossed the line *a g* at *k*, and also, when the sides of the triangles *g n m*, *n o m*, *o h m* are measured the line *o a* be also measured, noting again the distance at the intersections: these lines in the plotting of a work will be an infallible check on the accuracy of the measurement of the sides of all the triangles with which they are connected. The principal lines and triangles being thus measured, fill in one of the triangles as *b c f*: commence at any of the angular points, such as *f* and run a line to the opposite side to *w*, leaving pegs, as at *t* and *u*: then measure the line *f w*, noting the distances at the pegs *t* and *u*—also from the point *w* measure the distance to the nearest mark *y*, previously made on the line A B. From the point *w* run again a line *w k*, leaving a mark at *l*, and at the point *k*, take the distances to the nearest marks as before at *w*. After the same manner, measure also the lines, *w p*, *p t*, *t q*, *&c.*, taking offsets as before, directed to all the hedges within ordinary distances; and so continue from one triangle to another until the whole is surveyed.

There are two methods of executing surveys with the compass. One, is to enter the bearings and distances, as they are taken, in a field-book, and to plot the survey from them afterwards; the other, is to lay down the bearings and distances at once on paper without any entries being made in the field-book. An example of each method will now be given.

Surveying with the Compass and Field-Book.—The following implements will be required:

A Measuring Chain.

Ten Arrows.

One or two Staves, for placing as marks at the stations.

A Field-book for registering the observations and measurements.

The 100 feet chain is divided into links of one foot each; and certain brass marks fixed on it, at ten feet distance from each other, show at once any number of feet less than 100. The arrows are stout pins of iron wire, about twelve inches long. The field-book, of the size of a common memorandum book, has upon every alternate page, two lines drawn lengthwise down the middle, at about three-quarters of an inch apart. The blank page adjoining is used for making notes.

Let A (Pl. I, Fig. 1) be a point, on the bank of a channel or river, whence a survey is to commence. The compass is to be set up at A, if a stand is used, or else held in the hand, and a man with a staff having being sent to B, where the channel makes a bend, the sights of the instrument are directed to the staff, and, on the card settling, it is found that the vertical hair cuts the 41st degree. That bearing is to be entered at the bottom of the field-book between the lines. The next step is to measure the distance from A to B. To do this, an assistant takes one end of the chain, and proceeds towards B, until desired to stop by the person holding the other end. The latter places himself over the point where the instrument stood, and motions the chain leader, who is facing

Fig 1.

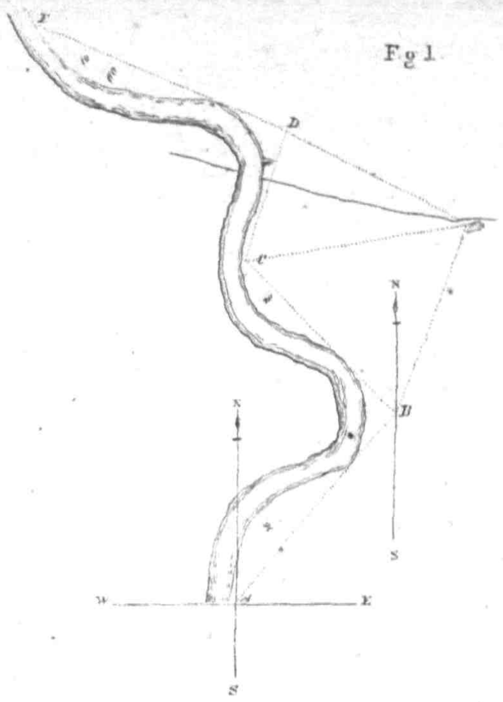
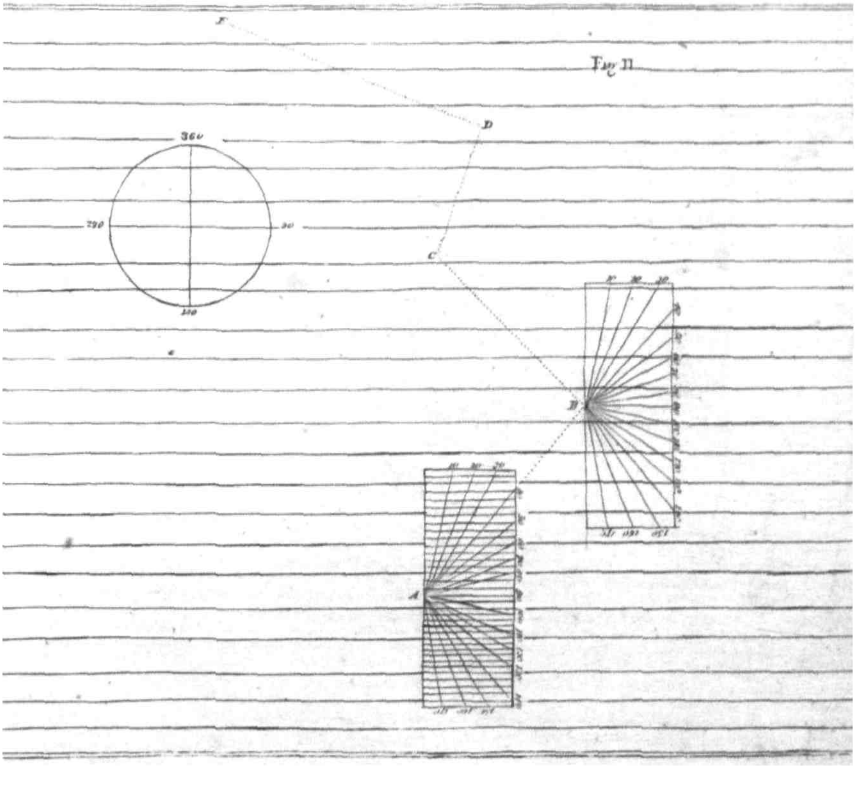
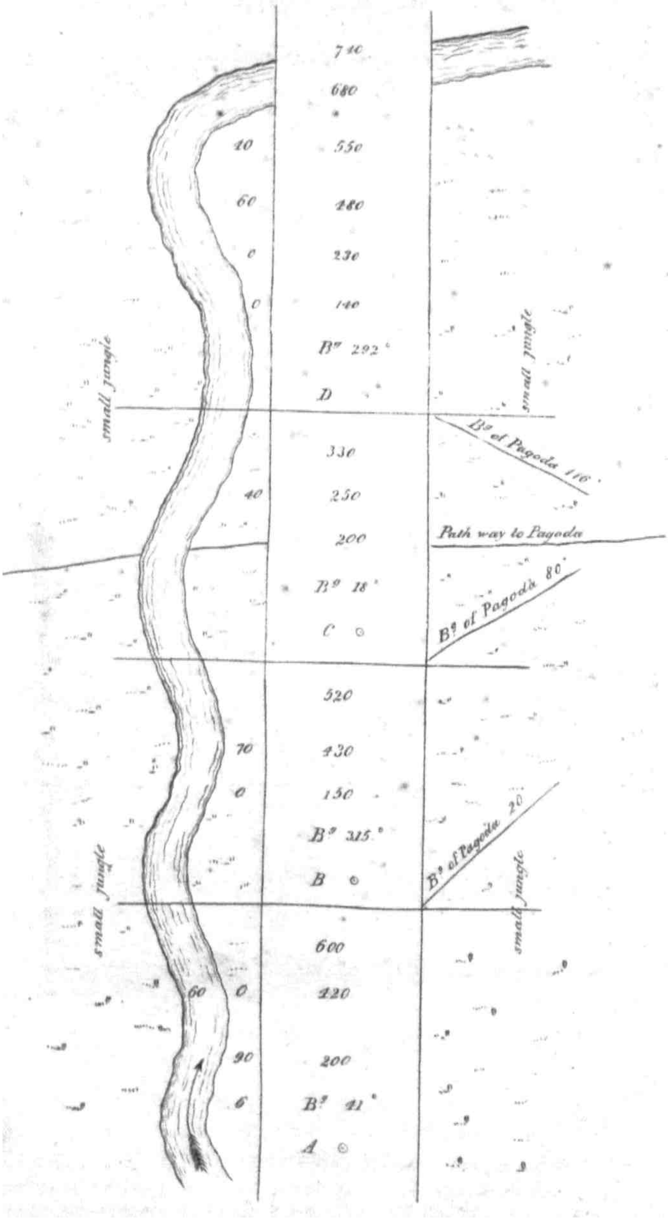


Fig II.



Form of Field Book



him, to move right or left, until he is exactly in a line with a staff at B. The chain is then drawn tight, and left on the ground while any offsets, that may be necessary, are taken.

Offsets are measurements to either side of the chain, and usually perpendicular to it, to determine the distance of a building, hedge, &c., from the chain line. Offset measurements may be made by pacing, or with a wooden rod. Pacing does very well when great accuracy is not required, and the eye is a sufficient guide for the direction, so as to go perpendicularly to the chain line. In surveying by linear measurement alone, *oblique offsets* are made in pairs from different points in the station line to the same object, in order to determine its position with more accuracy than is attainable by a single rectangular offset. For example, see Fig. 2, Pl. A, the position of the object D is found by measuring to it a pair of offsets BD, CD, from two different points, B and C, in the station line ABC. This process, in fact, belongs to the method of surveying by *triangles*, BDC being a triangle of which the three sides are measured. The nearer the angle between the two offsets, BDC, approaches to a right angle, the more accurately is the position of the object determined, and care should, therefore, be taken to make that angle neither very acute nor very obtuse. If a check on the accuracy of the operation is desired a third offset, ED, may be measured to the object from a third point E, in the station line. The principal objects for which the additional accuracy given by oblique offsets is desirable, are corners and intersection of boundaries, angles of buildings, mile stones and the like. Where the object is a corner of a building, such as D in Fig 2, it is convenient to make each of the offsets, if possible (or at all events one of them), lie in a straight line with a face of the building, and so to determine the direction of such face or faces.

The chain leader has ten arrows, one of which he sticks into the ground at the end of the chain, or makes a cross if the ground is hard, and lays the arrow down: he then draws the chain forward, giving it a cast to the right, so as to keep it from disturbing the arrow he has placed. When the chain follower comes within a few feet of the arrow placed at the end of the first chain, he stops the leader, places him in a line with B, and takes up the arrow. Thus, the measurement proceeds—the leader always depositing an arrow at the end of every chain, which is taken up by the follower. When the eleventh chain is measured, the latter runs forward, and restores the ten arrows to the leader, who should count them to see that he has just ten, and place one to mark the eleventh chain; 1,000 is then noted, and so on to 2,000, 3,000, &c.; and on arriving at the end, he has only to count the arrows in his hand, adding whatever number of feet are indicated by the brass marks upon the chain; and in this way he will rarely make any mistake.

In the present case, the distance from A to B is 600. At A, an offset of 6 is taken to the channel bank, and at the distance of 200, an offset of 90; at 420, the chain passes along the edge of the channel. These measurements, and a rough sketch of the channel are entered in the field-book as shown in Plate II.

When the measurement of the first station is completed, the instrument is to be set up at B, over the spot where the staff stood. A staff

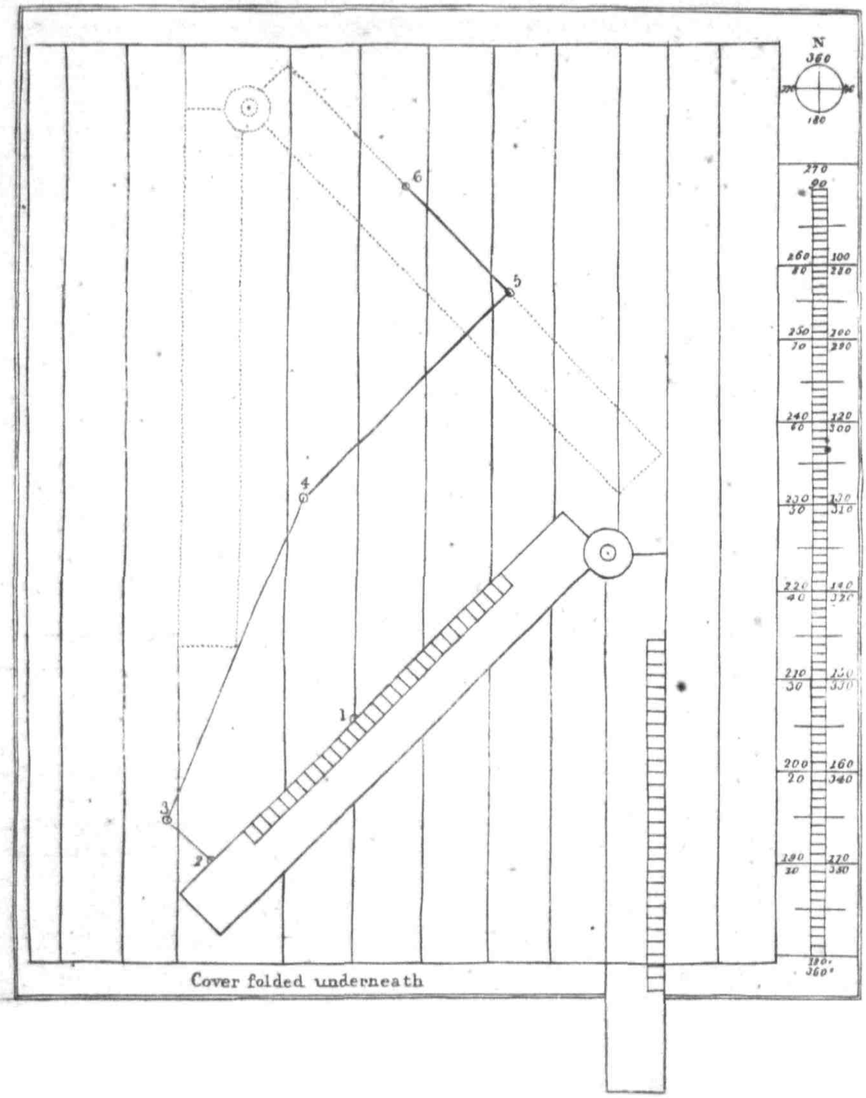
To return to the figure—through B draw a line, parallel to N S, the meridian of A, to represent the meridian of B; apply the protractor to its edge and place a mark against the 135th division (135 being the excess above 180° of 315°, the bearing of C from B). Place the protractor with its edge coinciding with the mark and B, draw a line from B towards the left, and take B C = 520. Also, placing the protractor at B, mark off 20°, the bearing of the pagoda, and draw a line in that direction. The points D and E are obtained in the same way as B and C. At C, the bearing of the pagoda (80°) being marked off, and a line drawn, its intersection with the bearing from B fixes the position of the pagoda. Should the bearing from D also pass through the same point, it shows that the measurements and angles have been correctly taken in the field. Hence, in measuring a road, any remarkable object that may be visible from several stations, and not more than from half to three-quarters of a mile distant, that the intersections may not be too acute, should have its bearing frequently taken as a check upon the work.

When all the stations have been fixed, the offsets are to be plotted; here a slip of paper divided according to the scale is extremely useful. First, mark a point at 200, and another at 420 from A. Turn the slip of paper at right angles to the line A B, and at the point A, set off 6; then, at 200, again use the slip scale and mark 90 to the left: at 420, the offset is 0. Join these points of the cross measurements, or offsets, and one bank of the channel will be obtained. The offsets from the other station lines are to be laid off in the same way, and afterwards, the other bank of the channel should be drawn at the distance of 60 from the one to which offsets were taken.

Surveying with the Compass and Sketch Book.—The Surveyor will require to take out, a sketching case, about ten or eleven inches square, an ivory rectangular protractor, and a black lead pencil. The paper fits into the sketching case, and must be ruled all over with very fine lines; these are to be exactly *parallel* to each other, and at *unequal* distances, varying from a quarter to half an inch apart. The purpose to be answered by ruling the lines at unequal distances will be presently seen. The protractor is six inches long, and an inch and three quarters wide, having *across it* a number of very fine lines at right angles with its length, and at equal distances from each other. These lines are regulated so as to form a scale of four inches to a mile, but may likewise be used for paces or yards.

To survey the same channel as in the last example, the compass is to be set up at A (Plate I, Fig. 2), and the bearing of B (41°) taken in the way already described. Now to protract, or lay down the bearing of B upon the paper, which has upon it the parallel lines at *unequal* distances, to be considered as *east* and *west*, and, therefore, not meridian lines, which are north and south. The protractor has across it, as already noticed, a number of lines. Now, fix on any convenient part of the paper, make a dot, and surround it with a small circle, thus ⊙, which denotes a station. Place the centre of the protractor at this point, and endeavour to make any one of the lines which are drawn across it, to coincide or agree with one of those upon the paper, being careful to keep the centre of

FIELD SKETCH BOOK & PROTRACTOR



the protractor very exactly on the point. This being effected, the protractor is adjusted, that is, lengthwise it will be north and south, while its ends will, of course, be east and west. Make a small mark on the paper at the 41st division, and draw a line from A through that mark. The distance from A to B is now to be measured, and to lay it off; upon the line in the sketch, apply the edge of the protractor, which has a scale marked on it, or use a slip of paper, on which a scale has been prepared, and mark off the distance. While measuring from A to B, the offsets are to be taken and the bank of the channel sketched: the first station is then complete. The other bearings and distances are taken in the way already described, and the points C D E laid down as in plotting from the field-book. The only use of the lines ruled on the paper, is to enable the protractor to be readily placed, with its long edge north and south at each station, without being obliged to draw parallel meridians through each, which would be inconvenient in the field.

As the time, that can be devoted to out-door work in this country is limited owing to the heat, the first of the above two methods, which is the more expeditious, is to be generally preferred; but in this, as in many similar matters, that plan should be adopted which each individual has found to answer best.

Howlett's Sketch Book and Protractor, (Plate III).—The method of surveying with this sketch book and protractor, does not possess any particular advantages over the two already described, but as it is practised in the road department, an account of it will here be given, taken from that of the inventor.

The proper paper for the sketch is medium bank post, as it admits of its being folded without injury. At distances of about half an inch apart, lines are to be ruled across the paper, perfectly parallel, with a hard pencil or faint ink, to represent meridians. The paper is folded over the inner flap of the book, to keep it steady; and the cover, being a little larger than the flap, preserves the paper from injury. Supposing the work to lie west of the point, where the survey is to commence, the right hand edge of the sheet should be folded uppermost, and so placed in the book that the meridians may be vertical; the upper part of the book is to be considered north.

The protractor is merely a common rule folding in two, with a stiff joint, entirely plain, except having scales of paces or yards on its edges.

On the edge of the book, a scale of chords, to a radius equal to half the length of the rule, is placed, by which the rule will be accurately opened with one hand, in the manner of a pair of compasses, to any angle as far as 90°; and as the outer edges are parallel to the inner, the angle may be plotted by drawing a line against either edge. The scale of chords is figured in such a way, that the protractor, by a method that is simple and obvious, is capable of setting off angles to 360°, though it only extends to 90°. At the top of the scale, a little circle is drawn, as a sort of key to the figuring of the scale, and which will prevent all mistakes as to the direction of the forward station.

As for general service it is desirable that all the instruments should,

2

as far as possible, be general in their application; it is the excellence of this method, that all surveys may be plotted, whether made by a *compass reading to 90°, 180°, or 360°.*

Suppose the observer is at station 1, going southward 225°, he opens the rule to 225°, according to the scale (45° in reality), and slides the *right* side of the rule against the most convenient meridian, until the sloping side touches the station. Now, as he is going south-west, he draws a line in that direction; but if he had been going 45°, or north-east, he should have placed the rule in exactly the same position, only he should have drawn the line in the opposite direction. Again; suppose he has advanced to station 5, and is going north-west to station 6, he opens the rule to 315°, and places the *left* side against a meridian, and slides the sloping side to station 5, and draws the line in the direction he is going; but if the forward station had been south-east, or 135°, instead of north-west, this same angle (45° in reality), and position of the rule would be proper, only the line must have been drawn accordingly.

Hence, it is plain that only two positions of the rule are necessary; for by merely placing the rule right or left, and by drawing the line up or down, every angle with the meridian is obtained.

At first, it will be better to keep the joint of the rule towards the north, but it may be downwards; and, after practice, a person will use it promiscuously.

In use, the left cover of the book is turned under the other, which gives firmness; and the whole is so light, that the hand does not become tired.

Sketching Ground.—By any of the methods already described, a road, channel, or other boundary may be surveyed and its course laid down on paper. Should a survey of a small extent of country be required for irrigation or other purposes, bearings must be taken along the roads, channel and tank banks, boundaries of cultivated and waste land, &c.; and when these are protracted, a skeleton plan of the ground will be obtained. The shape of a tank, after its bank has been laid down, can be obtained either by taking bearings along its margin, or what will answer the purpose as well, by taking bearings from each end of the bank to two or three points on the margin, and then joining the points of intersection by an irregular line. Should the tank be empty, there will be no difficulty in ascertaining the usual water spread.

The method of measuring and protracting angles and distances, being work of a mechanical nature, is soon acquired, but sketching *ground,* by which uneven ground is to be understood, can hardly be learned from description, and much practice in the field will be required, before it can be done with facility and accuracy.

The contours of hills should be sketched in the field, with reference to the bearings that have been laid down, and not afterwards from notes in the field-book. While proceeding from station to station, should the line be over ascents and descents, the points where they begin and end must be marked, or should the line pass along the crest or foot of a hill, by taking offsets to it occasionally by pacing, a number of points will be obtained and the shape of the hill must be put in by the eye. The roads,

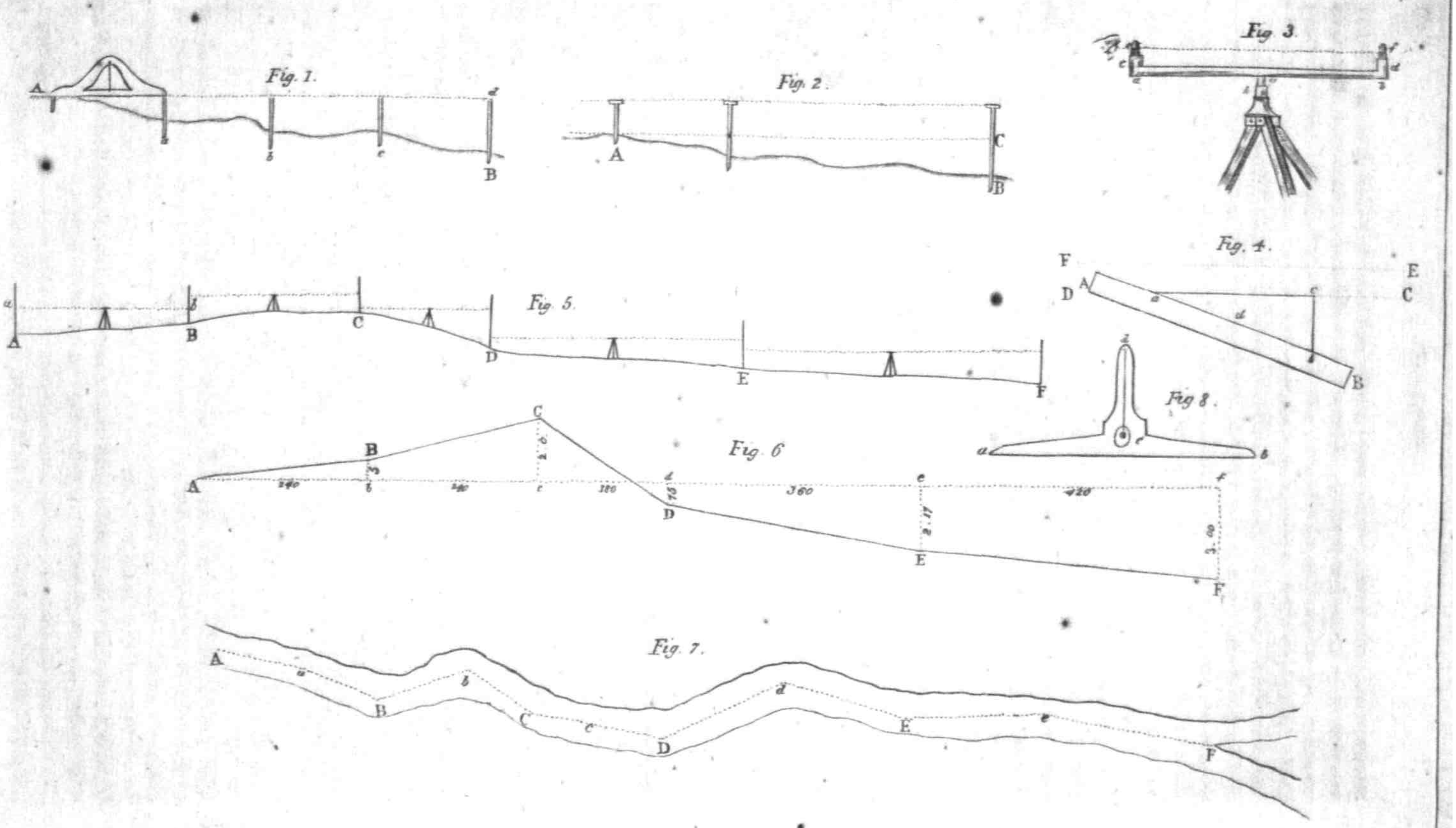


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6
240
240
180
360
420
2.17
3.00
Fig. 7.
Fig 8.

rivers, &c., and features of the ground may be sketched at the same time; but, in large surveys, the roads, rivers, boundaries of land, &c., are usually laid down preparatory to sketching the ground. The surveyor, then taking the sketch sheets, contaning these lines, examines the ridges, observes the sweep of a hill or the direction of a valley, and refers all to the points already laid down on the paper. He takes few measurements, except by the eye, but finds his place by taking bearings with the compass. He commences at the highest situation, and working his way downwards, is careful only to sketch the features he actually goes upon. Nothing can be more fallacious than to suppose the nature and slopes of any portion of ground not immediately under the eye. Every feature must be traversed, if he wish to insure accuracy. He had better touch in the hills lightly at first, until he is quite sure of being correct, occasionally holding the sketch so as to correspond with the ground, which is easily done by means of the fixed points, and observe whether the features on the paper agree with those of the country before him. He must be sure to take the bearings of all remarkable objects while at any situation that has been determined, as a little foresight may save the trouble of a return to it.

Section 2.—Levelling.

The Bricklayer's Level.—This instrument consists of a board *ab* (Pl. IV, Fig. 8), from 1 to 1½ inches thick, which should be well seasoned, that it may not crack or warp; another board *cd*, is morticed or otherwise firmly attached at right angles to the middle of the first, in such manner that their surfaces may be flush. A true perpendicular line to the under edge of *ab* (which must be perfectly flat and smooth) is now laid off, from the centre of the under side of *ab*, upon the surface *cd*, and is there strongly marked; a saw cut is made at the top of *cd*, in the direction of this line, from which a plumb line is supported, its weight or *bob* hanging in a whole *c*, cut through the bottom board, and large enough to give the bob some play in every direction without contact. The bottom board *ab* should be exactly 2, 3 or 4 yards long, from end to end, in order to give results of deviation from level in yards of length without calculation. If this instrument is correctly made, it will be evident, that on setting its bottom edge *ab* on a wall, or other surface that is perfectly level, the string of the plummet should accord exactly with the line scratched on *cd*, throughout its whole length; while on the contrary, if not level, the string will be thrown to one or other side of the line. To prove the correctness of the implement, place it as above, on a surface that it shows to be perfectly level; and such a one may always be made, by driving wedges under one end of a thick plank. After finding that the plummet hangs in its proper vertical direction, reverse the level by turning the two ends of the bottom plank into the opposite positions they before held; when, if the plummet retains its same parallel position to the line on *cd*, the instrument is perfect. If otherwise, half the error must be corrected by raising one end of the plank, and the other half, by altering the position of the line drawn on *cd*. By several reversions of this kind, the true position of the perpendicular line will be obtained, and then the instrument may be used with confidence.

The difference of level between two points A and B (Pl. IV, Fig. 1) may be obtained with this instrument, in the following way:

Drive a picket at A, down to the surface of the ground, and another, distant a few inches less than the length of the level at *a*, until the eye perceives that the head of the latter is nearly on a level with A; then set the level to rest on the two pickets, and the plumb line will show when their heads are truly level. A third picket is then driven in at *b*, a fourth at *c*, &c.: to the heads of which the level is successively applied; and the length of the picket B*d* is the difference of level required: the heads of all the pickets will then be on the same level, represented by the dotted line A*d*.

Boning Staves.—The operation, described in the last paragraph, is more quickly performed by means of *boning staves*, which are simply staves of equal length (usually three feet), having a T head. To level with their assistance, a mason's levêl is used for the first two pickets, as before; then a third picket being driven at any convenient distance, a boning staff is held upon each, and the third picket is driven down until the observer at A can see that the upper surfaces of the T heads are all in an exact horizontal line: the operation may then be continued by driving in a picket beyond B, to which the boning staff at A must be removed. Instead of driving a picket at B, a measuring rod is often used, which being held perfectly upright, a boning staff is pressed against it, and caused to slide up or down until its head agrees with those of the other two; when the difference of level is, of course, the distance between the foot C of the boning staff, and B, that of the measuring rod. Observe, that the boning staves are to be held transversely, or at right angles to the position in which they are shown in the diagram (Pl. IV, Fig. 2). Uniform slopes, such as those required in making roads, may also be obtained by *Boning*. The operation is performed by driving a picket at the top, and another at the bottom of a given descent for the distance; upon these, two boning staves are held while intermediate pickets are driven down, until boning staves, held on the heads of the latter, are seen to be in the same inclined plane with those placed at the top and bottom of the slope.

The French Water-level.—This instrument possesses the great advantage of never requiring any adjustment, and does not cost one-twentieth part of the price of a spirit level. From having no telescope, it is impossible to take long sights with this instrument; and it is not, of course, susceptible of very minute accuracy; but, it might be used with advantage by maistries, when employed on the repairs of large tank banks and in clearing channels. The following description, with the assistance of the sketch, will enable any person to construct one for himself without further aid than the workmen to be found in most villages. Pl. IV, Fig. 3, *ab* is a hollow tube of tin, or other metal, about half an inch in diameter, and about three feet long; *c* and *d* are short pieces of tube of the same or larger diameter, into which the long tube is soldered, and are for the purpose of receiving the two small bottles, *e* and *f*; the ends of which, after the bottoms have been knocked out, are fixed in their positions with putty or white lead. The projecting short axis *g* works (in the sketch) in a hollow cylinder *h*; but it may be made in a variety of ways so as to revolve on any light portable stand. The tube, when required for use, is filled with water (colored with lake or indigo,)

till it nearly reaches the necks of the bottles, which are then corked for the convenience of carriage. On setting the stand tolerably level by the eye, these corks are both withdrawn (which must be done carefully and when the tube is nearly level, or the water will be ejected with violence) and the surface of the water in the bottles being necessarily on the same level, gives a horizontal line in whatever direction the tube is turned, by which the reading of the staff is obtained or its vane adjusted.

SPIRIT LEVELS.

When great accuracy is required, as in taking sections of ground for irrigation purposes, a spirit level is employed. Of spirit levels, there are now four in use—namely, the Y Level, Troughton's improved Level, Gravatt's Level, and one that has been lately introduced into this country, and called the second class levelling instrument. These instruments and their several adjustments will now be described, commencing with the simplest.

THE SECOND CLASS LEVELLING INSTRUMENT.*

It consists of a telescope, furnished with cross wires for determining the line of collimation, and having a tube, carrying the spirit bubble attached below it, beneath which is the compass box. The card is numbered to 360°, and the reading is at the side, differing in this respect from the other levels. Its principal use is, as a surveying instrument, for which it is well adapted; for, being very light, it is easily carried about, and being mounted on a stand, the angles can be taken with greater accuracy than with a prismatic compass held in the hand; and it is more useful, as the sections of nullahs and rivers can also be taken with it. It is not so accurate, however, as the instruments to be described presently, and the telescope will not remain horizontal, while the instrument is turned round on the staff head. *It requires but one adjustment, to fit it for use, which is thus performed.*

Set the instrument up midway between any two points, about eighty yards apart. Turn the telescope towards the staff, placed on one of them, and bring the bubble (by means of the milled head screw) accurately to the middle of the glass tube; observe at what height the cross wire cuts the staff; then, turn the telescope to the staff, placed on the other point, bring the bubble to the centre and observe the height as before. The difference of the two readings will, supposing the spirit level (as it ought to be) parallel to the axis of the telescope, be the difference of level between the two points. Now set up the instrument where one of the staves was, and measure its height accurately, and afterwards, direct the telescope towards the staff placed on the other point; then, if the difference between the reading and the height of the instrument, be the same as the difference of level before obtained, the level is in adjustment; if not, the capstan headed screw at the end of

* This instrument was first ordered, from Messrs. Troughton and Simms, by the late Captain Best; afterwards, several were made (except the level tubes) in Madras. Better instruments of the same kind have since been sent from England by Messrs. Troughton and Simms. The telescope being more powerful and the adjustments firmer, for ordinary purposes, they are probably as good as any kind of instrument, and they are very easy to use.

the spirit level must be turned, until the reading of the staff (less the height of the instrument) gives the exact difference of level previously ascertained.

THE Y LEVEL,

So called from the supports which carry the telescope resembling the letter Y, is the oldest description of instrument in use. The adjustments are easily made, but they are also easily deranged. The telescope in this instrument is usually made to show objects erect. Three adjustments are necessary: First, to place the intersection of the wires in the telescope, so that it shall coincide with the axis of the cylindrical rings, on which the telescope turns; secondly, to render the level parallel to the axis; and, lastly, to set the telescope perpendicular to the vertical axis, that the level may preserve its position while the instrument is turned quite round upon the staves.

To adjust the line of collimation.—The eye piece being drawn out to see the wires distinctly, direct the telescope to any distant object, and by the milled head screw at the side, adjust to distinct vision;* bring the intersection of the cross wires to coincide with some well-defined part of the object, then turn the telescope round on its axis as it lies in the Ys, and observe whether the coincidence remains perfect during its revolution: if it does, the adjustment is correct; if not, the wires must be moved one half the quantity of error, by turning the little screws near the eye end of the telescope, one of which must be loosened before the opposite one is tightened, which, if correctly done, will perfect this adjustment.

To set the Level parallel to the line of collimation.—Move the telescope till it lies in the direction of two of the parallel plate screws, (the clips which confine the telescope in the Ys being laid open), and by giving motion to the screws, bring the air bubble to the middle of the tube, shown by the two scratches on the glass. Now reverse the telescope carefully in its Ys, that is, turn it end for end; and should the bubble not return to the centre of the level as before, it shows that it is not parallel to the optical axis, and requires correcting. The end to which the bubble retires must be noticed, and the bubble made to return one half the distance, by the parallel plate screws, and the other half by the capstan headed screw at the end of the level; when, if the halves have been correctly estimated, the air bubble will settle in the middle in both positions of the telescope. This, and the adjustment for the collimation, generally require repeated trials before they are completed, on account of the difficulty in estimating exactly half the quantity of deviation.

To set the Telescope perpendicular to the Vertical Axis.—Place the telescope over two of the parallel plate screws, and move them (unscrewing one while screwing up the other) until the air bubble of the

* The eye piece must first be drawn out until the cross wires are perfectly well defined; then the object glass moved till distinct vision is obtained without parallax, which will be the case if, on looking through the telescope at some distant object, and moving the eye sideways before the eye glass, the object and the wires remain steadily in contact; but if the wires have any parallax, the object will appear flitting to and from them.

level settles in the middle of its tube; then turn the instrument half round upon the vertical axis, so that the contrary ends of the telescope may be over the same two screws, and if the bubble again settles in the middle, all is right in that position; if not, half the error must be corrected by turning the milled head screw under one of the Ys, and the other half by the two parallel plate-screws, over which the telescope is placed. Next, turn the telescope a quarter round, that it may lie over the other two screws, and make it level by moving them; and the adjustment will be complete.

Before making observations with this instrument, the adjustments should be carefully examined and rectified, after which, the screw under one of the Ys should never be touched: the parallel plate screws alone must be used for setting the instrument level at each station; and this is done by placing the telescope over each pair alternately, and moving them until the air bubble settles in the middle. This must be repeated till the telescope can be moved quite round upon the staff head, without any material change taking place in the bubble.

TROUGHTON'S IMPROVED LEVEL.

This modification of the instrument has a very decided advantage over the Y level, inasmuch as in its construction it is more compact, and the adjustments when once made are less liable to be deranged; although, to a person unused to the instrument, they will appear at first more tedious to accomplish. The telescope rests on a horizontal bar, which turns upon the staff head. On the top of the telescope, and partly imbedded within its tube, is the spirit level, over which is supported the compass box by four small pillars; thus admitting the telescope to be placed so close to the horizontal bar, that it is much more firm than in the former instrument. The bubble of the level is sufficiently long for its ends to appear on both sides of the compass box; and it is shown to be in the middle by its coinciding with scratches made on the glass tube as usual.

The wire plate or diaphragm is usually furnished with three threads, two of them vertical, between which the station staff may be seen: and the third, by which the observation is made, is placed horizontally.

The telescope is generally constructed to show objects inverted, and as such a telescope requires fewer glasses than one which shows objects erect; it has the advantage in point of brilliancy, and when an observer is accustomed to it, the apparent inversion will make no difference to him. A diagonal eye piece, however, generally accompanies the instrument, and by it objects can be seen in their natural position. A cap is adapted to the object end of the telescope, to screen the glass from the rays of the sun, or from the rain; when the cap is used, it should be drawn forwards as much as possible.

The requisite adjustments for this instrument are the same as those of the Y level, *viz.*, that the line of collimation and the level be parallel to each other, and that the telescope be exactly perpendicular to the vertical axis; or, in other words, that the spirit bubble preserve its position while it is turned round horizontally on the staff head. The

for Troughton's level. The operation of collimating upon levels on Gravatt's construction may appear tedious and complex, but after a few trials it will be easily understood and performed in a few minutes, and when once perfected, it will scarce ever need to be repeated.

LEVELLING STAVES.

The old pattern levelling staves consist of two parts, capable of being drawn out when considerable length is required. They are divided into feet and hundredths, or feet, inches and tenths; and have a sliding vane, painted half black and half white, or with a black lozenge on a white ground; the vane being raised or lowered by the assistant until the central line corresponds with the horizontal wire of the telescope, the height of the vane, noted on the staff, is the height of the apparent level above the ground at that place. The new levelling staves, which have now nearly superseded the others, have no vane to slide up and down, but the face of each staff is made broad enough to contain sufficiently large graduations and figures for the observer to read with certainty to the one-hundredth part of a foot, at the distance of seven or eight hundred feet. The staff consists of three parts, which pack together for carriage in a neat manner; and when opened out for use, form a staff seventeen feet long: the whole length is divided into hundredths of a foot, alternately colored black and white, and occupying half the breadth of the staff; but for distinctness, the lines denoting tenths of feet are continued the whole breadth, every half foot or five tenths being distinguished by a conspicuous black dot on each side.

METHOD OF LEVELLING WITH A SPIRIT LEVEL.

When the difference of level between two points A and F (Pl. IV, fig. 5) is required, and also a section of the intervening ground, the method of proceeding is as follows: Plant the spirit level* about midway between A and a point B, at any convenient distance, which need not be exactly in line between those points. Press the legs of the stand firmly into the ground, and draw out the eye piece of the telescope until the cross wires appear perfectly well defined; then, directing the telescope to a levelling staff held at one of the stations, turn the milled head screw at the side until the smallest graduations on the staff can be seen with clearness; that these two adjustments be very carefully and completely performed, is of more consequence than is generally supposed, for upon them depends the existence or non-existence of instrumental parallax. Having made the above adjustments perfect, bring the spirit bubble into the centre of its glass tube, which position it must retain unmoved in every direction of the instrument; or in other words, the bubble must indicate a true level during the time the telescope is turned completely round horizontally on its staff head; this is accomplished by bringing the telescope successively over each pair of the parallel plate screws and giving them motion, screwing up one while unscrewing the other to a corresponding extent.

The level being now prepared for observation, an assistant holds up the staff at A, either resting it on the ground, or what is better, upon a

* One of the larger levels and the new levelling staves are supposed to be used.

peg driven down to its surface—he must be careful to hold it perpendicularly. The observer now directs his telescope upon the staff, and when nearly in the right direction let him turn the clamping screw, after which, by means of the slow motion screw, the telescope is adjusted with greater exactness upon the staff, when the number of feet and parts of a foot are to be carefully noted, as cut by the horizontal wire of the telescope, and represented by *a* in the figure; the dotted line *a b* representing the line of sight or visual ray. The assistant then places his staff on a peg at B, and the observer (taking care to notice that the bubble of his level continues in the centre of its tube) directing his telescope reads off as before. Before removing the staff from A, its distance from the instrument must be measured, and its bearing by the compass noted. The distance of B from the instrument and its bearing must also be taken and entered in the field-book, together with the readings of the staves, and the height of the centre of the telescope above the ground. The instrument being then successively placed at convenient situations between BC, CD, DE, EF, the same observations are to be taken and entered in the field-book, which may be of the subjoined form:

LEVELLING FIELD-BOOK.*

No. of Stations.	Back Bearing.	Back Distance.	Fore Bearing.	Fore Distance.	Back Level.	Intermediate.	Fore Level.	Difference.		Reduced Levels.	
								Rise.	Fall.	Above Datum.	Below Datum.
1	190°	120	22°	120	4·65	4·40	4·15	·50		·5	
2	160	120	19½	120	4·68	3·93	3·18	1·5		2·	
3	188	100	12¼	80	4·12	4·52	6 87		2·75		·75
4	154	180	15	180	4·51	4·75	5·93		1·42		2·17
5	179	200	10½	220	4·46	4·80	5·29		·83		3·00
					22·42		25·42	2 0	5·00		
							22·42		2·		
							3·00		3·00		

The first forward reading 4·15, at B, being less than the first back reading 4·65, at A, shows that the ground rises, and the difference ·5 is

* The columns need not be placed in the same order as in this example, should another arrangement be found more convenient. The columns of figures should occupy one page of the book, and the opposite page should be left for describing the situations of the staves, the nature of the ground, &c., and for entering cross sections of the channel.

to be entered in the column of *Rise.* The third forward reading 6·87, at D, being greater than the third back reading 4·12, at C, the ground falls, and the difference 2·75 is entered in the column of *Fall.* These two columns show the difference of level from station to station. The next two columns show the difference of level between each station and the starting point or datum, and the entries are obtained by adding or subtracting the figures in the two preceding columns. Thus, the point B being shown to be ·5 above A that quantity is entered in the column headed *Above datum;* the next station C is also higher than B by 1·5 and, therefore, the sum of ·5 and 1·5, or 2 feet, will be its height above the datum; again, D is 2·75 *below* C, therefore the difference between 2·75 and 2, or ·75 is the quantity it is below the datum, and the entry is made accordingly.

It is not necessary to make the additions and subtractions in the field, but it is better to do so, in order that they may serve as checks on the readings of the staves. It is a proof that the field-book has been correctly kept, when the difference between the totals of the back and forward stations, and that between the totals of the rises and falls, agree with the last reduced level; thus, by reference to the above example of a field-book, it will be seen that this condition is fulfilled; 3 feet appearing in the proper columns as the quantity F is below A.

When merely the difference of level between two points A and F is required, it will not be necessary to measure distances or to take bearings, and the only entries to be made in the field-book will be the back and forward readings of the staves: the difference of any two of the readings will show the difference of level between the places of the back and forward staff; and the difference between the sum of the back sights, and the sum of the forward sights will give the difference of level between the extreme points. Should the sum of the forward sights exceed the sum of the back sights, it shows that the point to which the levels have been taken is below the starting point and *vice versâ.*

When the ground slopes regularly, rather long sights may be taken, but when the slope is irregular, the sights must be short, otherwise an accurate section cannot be taken, and indeed on all occasions, very long sights should be avoided.

The points between which levels are taken should be carefully described; it is not sufficient merely to take the levels from the head of— channel to the bed of—bank; for, such loose expressions, after a few weeks, puzzle even the person who took the levels which become useless to others.

The proof of the accuracy of a levelling operation may be obtained by going over the same ground again in an opposite direction, that is, beginning the second examination where the first ended, and going back to where it began, to ascertain if the results tally in both cases; and in doing this, it is not necessary to adhere to the stations before used, with the exception only of those that have to be compared together. Frequent opportunities should be taken to refer levels to buildings or other permanent marks, and when the survey passes by standing water, the staves

should be placed at the edge to see if the instrument is in adjustment. When levels are being taken along the edge of a backwater communicating with the sea, regard must be had to the state of the tide.

Drawing Sections.—To draw the section, rule a straight line A *f* (Plate IV, Fig. 6), to represent a horizontal line at the level of A; this is termed a *datum line:* along it set off A*b* equal to 240 (120+120) feet, namely, the horizontal* distance from A to B as entered in the field-book: from the point *b*, raise a perpendicular, and make *b* B=·5, join AB. Take *bc*=240 feet and make the perpendicular *c*C=2 feet, join BC. In the same manner proceed with the section, letting fall or raising perpendiculars *d*D, *e*E, &c., according as the field-book entries carry the section below or above the datum line A*f*. When a section is made of considerable length for irrigation or other purposes, two scales are used, one for the horizontal distances, the other for the vertical heights and depths; which produce a caricatured representation of the country; but by making the vertical scale much larger than the horizontal one, the depths of cutting and embankment required in the execution of road or channel works, is shown with greater clearness than if both scales were equal. The starting and ending points should be described on the section, and also the permanent objects to which the levels have been referred in their course.

If it be required to plot the bearings, and thus lay down the course of the channel or road, along which the levels have been taken, it is done in the way described in the last section, except that as bearings have been taken only at every other station, all the back bearings, except the first, must be drawn in the opposite direction. Thus, let *a* (Fig. 7) represent the spot where the instrument was first set up. Draw a line through it to represent the meridian and lay off the back and forward bearings in the usual way, also the distance to the back and forward staves; the positions of those staves A and B will then be fixed. Draw a meridian through B and lay off the bearing taken to it from the second position of the instrument but in an opposite direction, that is, if the back reading be greater than 180° the line must be drawn to the right or east of the meridian, if less, to the left or west. Make B*b* equal to the second back distance and the position of *b* will be fixed. In the same way the positions *c, d, e,* of the instrument will be obtained by laying off from C, D, E, the back bearings in the opposite direction, and the positions of C, D, E, F, will be fixed by laying off from *b, c, d, e,* the forward bearings in the usual way. The reason of this rule will be apparent by considering that if M is due north of N, N must be due south of M, and whatever may be the bearing of N from M, that of M from N must be exactly the reverse. Hence, when sketching ground and filling in a survey, the surveyor may find his place in it by taking the bearings of two points already laid down in his sketch, and protracting from those points the opposite bearings; their intersection fixes the place sought.

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* The distances are measured on the slopes of the ground, and are, therefore, not the horizontal distances between the staves, but corrections on this account need not generally, be made; indeed, when the rise or fall is slight, the difference between the hypothenusal, or surface, and horizontal measurements is scarcely perceptible.

Curvature and Refraction.—Hitherto a level line has been considered a straight line, but a true level is a line everywhere at an equal distance from the centre of the earth, and the earth being a sphere, the line is the circumference of a circle. The line of sight of the telescope of the level, is a true horizontal or level line at the point where the instrument is set up, but from that point each way it commences to rise above the true level. The difference between the true and apparent level of any two points is scarcely perceptible when their distance from each other is less than 1,000 feet. In practice, therefore, no correction is applied during ordinary levelling operations for less distances than 1,000 feet. On all occasions, when from the distance between two stations, in levelling, a correction becomes necessary on account of *curvature*; a second correction is essential, for *refraction*. The effect of refraction is to cause all objects, when viewed from a distance, to appear higher than they really are. Corrections on account of curvature and refraction are very seldom applied in practice, as by the method of levelling, usually adopted, their effects are done away with. By merely placing the instrument about midway between the station staves and taking the difference of the readings of the staves for the difference of level between the two points, the effect of curvature is removed, as well as that of atmospheric refraction, which will affect both observations alike.

SECTION 3.—Of Drawing Instruments, &c.

The uses of the compasses, drawing pens, &c., found in the ordinary cases of instruments, are sufficiently obvious, and it will not be necessary to describe them. A small well finished set will be found more useful than the large sets of inferior make commonly met with in India, which are a source of constant annoyance and dear at any price. An ivory rectangular protractor will be required for laying off angles, and for drawing parallel lines, the Marquois scales and triangle will be found the most convenient. The following is the method of using them:—

Marquois Scales.—The triangle (which should be of large size) is right angle, and the hypothenuse, or longest side, *ab* (Pl. IV, Fig. 4) is three times the length of the shortest, or perpendicular, *bc*. First, for drawing parallel lines, by means of one ruler and the triangle. Suppose that a line EF is to be drawn parallel to CD; place the triangle so that one of its edges shall agree with the line CD, and then apply the ruler AB to the opposite edge; press the latter so as to keep it steady, and then slide the triangle along the scale towards A, until it arrives at the point through which the intended line is to be drawn.

But the lines may not only be drawn parallel, but drawn at measured distances. On each edge of the rules are placed two *scales*, the one close to the edge, the other within this. The outer scale may be termed the artificial scale, the inner one, the natural scale: the divisions on the outer are exactly three times longer than those on the inner scale—bearing the same proportion to each other, that the shortest side of the right angled triangular ruler does to the longest. The triangle has a line or mark at *d*, to serve as an index or pointer; when in use, this mark should be made to coincide with the O division of the scales: the

numbers on the scales are reckoned both ways from this division; consequently, by confining the ruler, and sliding the triangle either way, parallel lines may be drawn on either side of a given line, at any distance pointed out by the index on the triangle. Thus—looking at the scale marked 20 (not shown in the Figure), which signifies that the *inner* scale is divided to 20ths of an inch—suppose that from a given line, it were required to draw a parallel line at 4-20ths of an inch distance, it will only be necessary to adjust the mark on the triangle at O, slide it 4 divisions, and the object is effected; for the edge of the triangle only moves through one-third of the space passed over by the index.

The scales given are 20, 25, 30, 35, 40, 45, 50, 60; which means that the smallest divisions of the *inner* scale are in the proportion of those several numbers to one inch. When the outer scales are taken as the natural scales, and it is required to draw a line parallel to another at the distance of a certain number of divisions, it will be necessary to slide the mark on the triangle three times that number.

It is obvious, that by placing the rulers side by side, and alternately moving them, being careful to keep one always confined, that a parallel line may be drawn at any distance.

The ruler and triangle are likewise useful when a perpendicular, or a line at right angles to another is wanted. For instance, if a line be drawn along the edge *cb*, it will be at right angles to DC.

Marquois scales and triangle will be found very useful in architectural and all kinds of plan drawing; a little practise will enable a person to use them with facility, and to execute plans very rapidly with their assistance.

Diagonal Scales.—In the simply divided scales, one of the primary divisions is sub-divided only into ten equal parts, and the parts of any distance which are less than tenths of a primary division cannot be accurately taken off from them; but, by means of diagonal scales, two of which are drawn on the ivory protractors, the parts of any distance which are the hundredths of the primary divisions are correctly indicated.

If it were required to measure 5·7 on the scale, it would be necessary to place one end of the compasses, on the lowest parallel at the fifth primary division, or vertical line, and extend the other to the seventh diagonal line; but, if it were required to set off 5·74, one end of the compasses must be still placed on the fifth vertical line, but four parallels higher up, and the other point extended to the same diagonal as before on that parallel. The primary divisions may be taken either as units, tens or hundreds, and the general rule for taking off any number to three places of figures is,

On the parallel indicated by the third figure, (the one to the right,) measure from the diagonal indicated by the second, to the vertical indicated by the first.

Map drawing.—The roads, channel and tank banks, boundaries of cultivated and waste land, &c., are first protracted in pencil and then

drawn with Indian ink. The various features which the face of the country presents, are expressed by certain conventional signs contained in the *Map* at the commencement of this chapter; of these, the drawing of hills alone presents any difficulty. Having drawn the forms of the hills on paper, their slopes are indicated by shading, which may either be done with strokes of the pen, as shown in the map, or with washes of Indian ink or neutral tint; for the latter, two camel-hair brushes are used, one to lay on the tint with, the other filled with water to soften it down. Gentle slopes are represented by pale shades; steep slopes, by dark shades; and broken precipitous ground, by touches of the pen or brush on the slopes.

The plans need not always be colored, but, when they are, the coloring may be done in the following order. After the survey has been pencilled, the banks of rivers, channels and tanks must be drawn with a pen dipped in Indian ink, and the roads with one dipped in lake or burnt sienna. The rivers and tanks are then to be colored with blue, (indigo or Prussian blue) and the shapes of the hills faintly marked with Indian ink or neutral tint. A pale wash of green (sap green or a mixture of indigo and yellow ochre) is then to be passed over all the uncultivated ground, leaving the dry grains to be colored with burnt sienna, and the rice fields with blue. The shading of the hills is next to be completed, the buildings colored with lake, and the trees and other details put in with a pen or brush. Lastly, the names of the places are to be written or printed, and a scale and meridian drawn. As a general rule, the top of the plan should be the North, the meridian being drawn parallel to the sides, but sometimes, in order to get the survey better on the paper, it will be more convenient to draw the meridian in another direction. The proper method of drawing the North and South line is to lay it off parallel to that line, from which the first bearing was protracted. It is important that this should be done correctly. The *fleur de lis* to mark the North should be plain, neat and small. The names of places should be written parallel to the top and bottom of the plan, and the names of tanks and rivers in them, following their outline.

Half a dozen colors will be quite sufficient both for maps and architectural drawings.

Drawing paper should be damped with a sponge and clean water, on the opposite side from that on which the drawing is to be made, and allowed to dry before being used. When a plan is to be mounted on cloth, the latter should be evenly stretched on a table, and its edges glued down or fastened with tacks. The drawing is to be placed with its face downwards, on a clean table, and its back pasted; it is then to be taken up and turned over on to the cloth, and having placed a sheet of clean paper over its face, by rubbing with a soft cloth it may be made to adhere to the cloth in all parts. When the plan is of great length, it will be best to paste only a portion at a time, and adjust it on the cloth before the next is pasted. The cloth should not be taken up till it is thoroughly dry.

CHAPTER II.

MATERIALS USED IN BUILDING.

SECTION I.—Bricks and Tiles.

OF BRICKS.

The qualities to be aimed at in making bricks for building purposes are :—soundness, that is, freedom from cracks and flaws; hardness, to enable them to withstand pressure and cross-strain; regularity of shape, that the mortar by which they are united may be of uniform thickness to insure uniformity of settlement; uniformity of size, that all the bricks in a course may be of the same height. A good brick, moreover, should give a clear ringing sound when struck, and should not much increase in weight after being immersed in water.*

The operations of the brick-maker may be classed under five heads: viz.; Choice and preparation of the earth; Tempering, Moulding, Drying, Burning.

These operations will now be described, in order; first, as practised in the vicinity of Madras; and, secondly, as practised at the Head Quarters of the Sappers at Mercara. The account of brick-making at Madras will apply to most other places in India. At Mercara, the English method is to a great extent followed.

Brick-making at Madras.

Choice and Preparation of the Earth.—It is of considerable importance to examine clay before it is made into bricks, in order to ascertain whether any addition can be made to it which will improve its quality. The proportion of sand to be used with any clay, must be greater, the more such clay is found to contract in burning; but the best clays are such as require no sand. The best brick earth consists of a *mixture of pure clay and sand, free from pebbles of every kind, and such* earth is often found in a natural state. Bricks made of pure clay will warp and crack in burning, and those made of soil containing sand in excess have but little strength, and are easily crushed and are heavy. About five parts of clay to one of sand form the best brick earth. That used at Madras is of very good quality.

From motives of economy, it is usual in this country, to make the

* A good English brick absorbs about a fifteenth of its weight of water. A Madras brick about a fifth.

bricks required for any work in its immediate vicinity, and consequently of nearly every description of soil; when that happens to be of a suitable nature, very excellent bricks are often obtained; when otherwise, the bricks are in a like degree inferior. It is not considered worth while to incur expense, on account of the carriage of bricks, from a greater distance than two or three miles, and such being the case, very little choice is left with regard to the earth. The mixing of two or more soils together, in order to produce a compound better adapted for brick-making, is rarely practised.

Before making bricks for a large work, it will be a good plan to send for specimens from the neighbouring villages, and from an inspection of these, and enquiring of the inhabitants, the most suitable spot for procuring the earth may be found.

In this country, the earth rarely undergoes any *preparation*, as that term is understood in England, viz., being dug up some months before it is wanted, and left in heaps to be mellowed by the frosts, which break up and crumble the lumps. Now, though there are no frosts in the greater part of India, yet the earth would be improved for the purposes of the brick-maker, if it underwent this *weathering previous to being tempered. Much of the goodness of bricks depends* upon the proper management of its first preparation, for the earth *itself, previous to its being wrought,* possesses very little tenacity; but by long exposure to the air and frost, and thoroughly working and *incorporating it together, it is converted into a tough,* gluey substance, in which state alone it is fit for moulding.

Tempering.—The tempering is performed by men treading the clay mixed with water under their feet. The vegetation having been removed from the surface of a piece of ground, it is dug up to a depth of six inches or a foot, and as much water as it will hold having been poured upon it, it is left till the next morning, when it is trodden under foot by men. The operation should be carried on for at least an hour, and repeated on three or four successive days, more water being added as required, and all pebbles should be carefully picked out and thrown on one side. To meet the cry for cheap bricks, the process of tempering has of late been very much shortened, men are often not employed at all to tread the earth; it is merely turned over for a few minutes with the mamooty and then carried to the moulder. The object of the tempering is to bring the earth into a homogeneous paste, for the use of the moulder, and the operation should not be performed hurriedly. The quantity of water will depend on the quality of the earth, but no more should be used than will suffice to make the clay so plastic that it can be moulded easily; about half a cubic foot of water to one of earth will generally be found a good proportion. If too much water be used, the bricks become dry and brittle; but if duly tempered, they will be smooth, solid, hard and durable.

Moulding.—Bricks are usually moulded in this country on the ground, and left to dry where they are made; indeed, it would not be possible to remove them at once, as is the custom in England, for they are moulded so exceedingly soft. The piece of ground should be level,

and made as smooth as possible, by the removal of the grass, stones, &c.: the bricks will then be nearly as good as if moulded on a board.*

The time of year when rain is unusual, should be selected for brick-making, for much loss is experienced when the operation is carried on in showery weather.

The moulds are of wood and made to strike one or two bricks; their internal dimensions should be a little in excess of those of the bricks intended to be made, in order to allow for the shrinking of the clay. The amount of shrinking depends on the nature of the clay; in some kinds, it is scarcely perceptible, and very considerable in others. Perhaps a twentieth will be a proper allowance to make, that is, a 9-inch brick will require a $9\frac{1}{2}$-inch mould.

The moulder, having dipped the mould in water, places it on the ground, and then taking up a sufficient quantity of tempered clay in his hands, throws it in, forcing it into all parts of the mould; the superfluous clay is then removed with a flat stick passed along the top of the mould or simply with a wet hand, and the mould being taken up and placed a few inches off, the same process is repeated.

The bottom of the moulds should be covered with a thin strip of iron, as wood wears away very quickly, and it is of the greatest importance that the bricks should be all made precisely of one size; a mould that is at all worn should be thrown aside. The admission of thin bricks into large works adds greatly to their cost, causing increased expenditure in bricks, chunam and workmen.

The substitution of machinery for manual labor, in the process of moulding, might, perhaps, be adopted with advantage in the vicinity of large stations, where there is a constant demand for bricks, also in the execution of large engineering works, but not generally, as the cost of moulding bears but a small proportion to the total cost of brick-making. Manual labor is, however, so cheap in India, that after all, it is doubtful whether the cost of machinery would be repaid by the saving in any case.

Drying.—Great attention should be paid to drying the bricks before they are burned; they should be protected from the direct action of the sun and wind, so that one part may not dry more rapidly than another, otherwise, the bricks will crack from the unequal shrinking. Very little care is, however, usual in this respect in India, and the bricks do not seem to suffer much from the want of it, the reason being, that they are generally made of earth containing a larger proportion of sand than enters into the composition of the best brick earth, and the excess of sand prevents any considerable cracking, notwithstanding the hurried manner in which the drying is performed. A better brick could be made from a purer clay, but then the tempering and drying would require to be conducted with greater care.

The bricks are left where moulded until dry enough to be handled;

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* In Bengal, bricks are often moulded on chunam terraces.

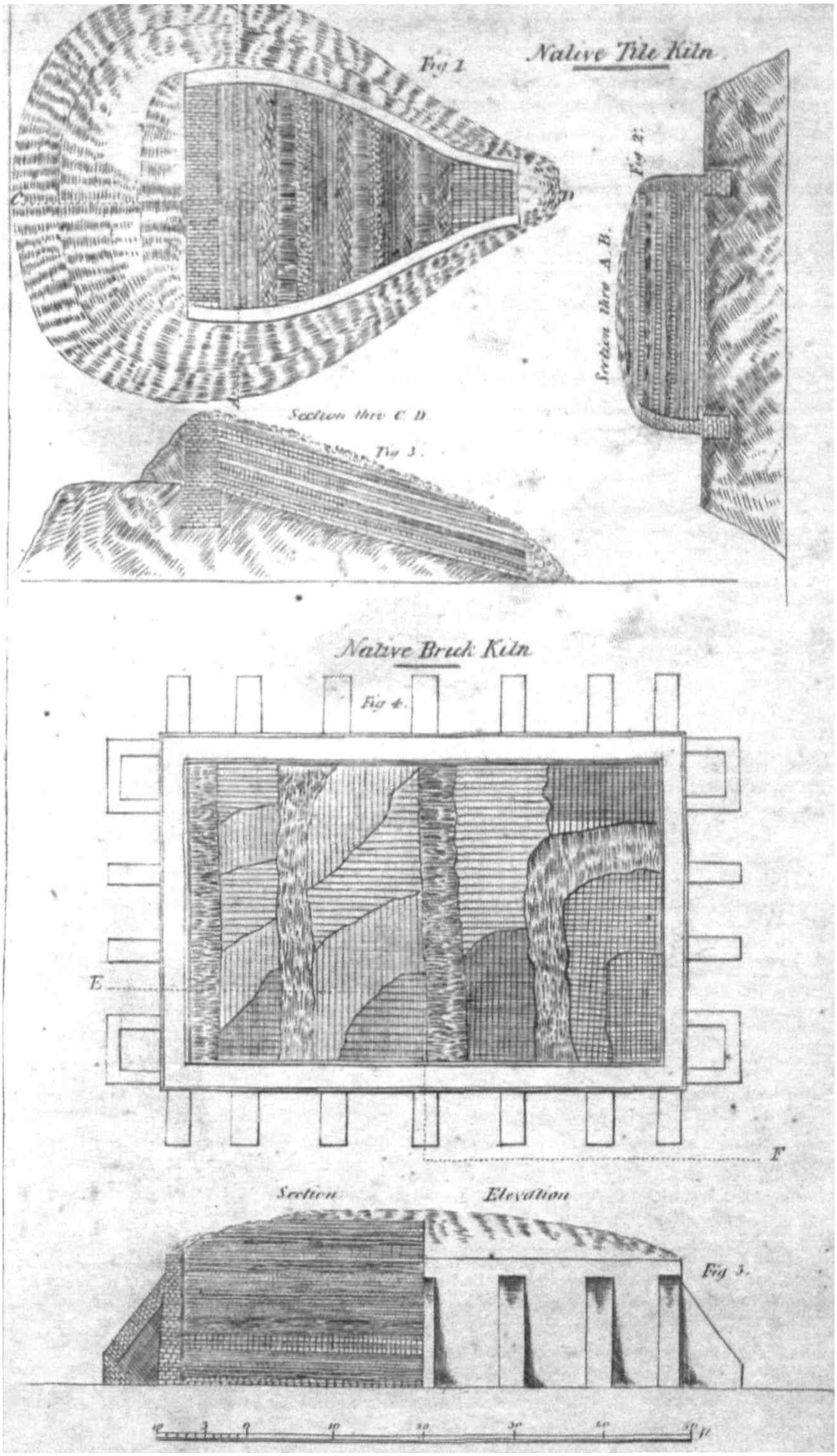
they are then taken up, the underside scraped and set on their edges, and often so left until they are wanted for the kiln. They ought, however, to be turned every other day. When a large number of bricks are to be burned together, to protect those that have been dried from being injured by the rain, or by cattle treading upon them, and also with a view to their taking up less space, they are stacked in heaps which are covered at top with palmyra leaves. The bricks should not be packed very close in the heaps, in order that they may be thoroughly dried by the wind passing between them. Not less than six days should be allowed for drying, but the time will depend on the nature of the clay and also on the weather.

Burning.—The bricks in this country are usually burned in *clamps* and the fuel employed is wood; *kilns*, properly so called, are not often constructed by the natives.

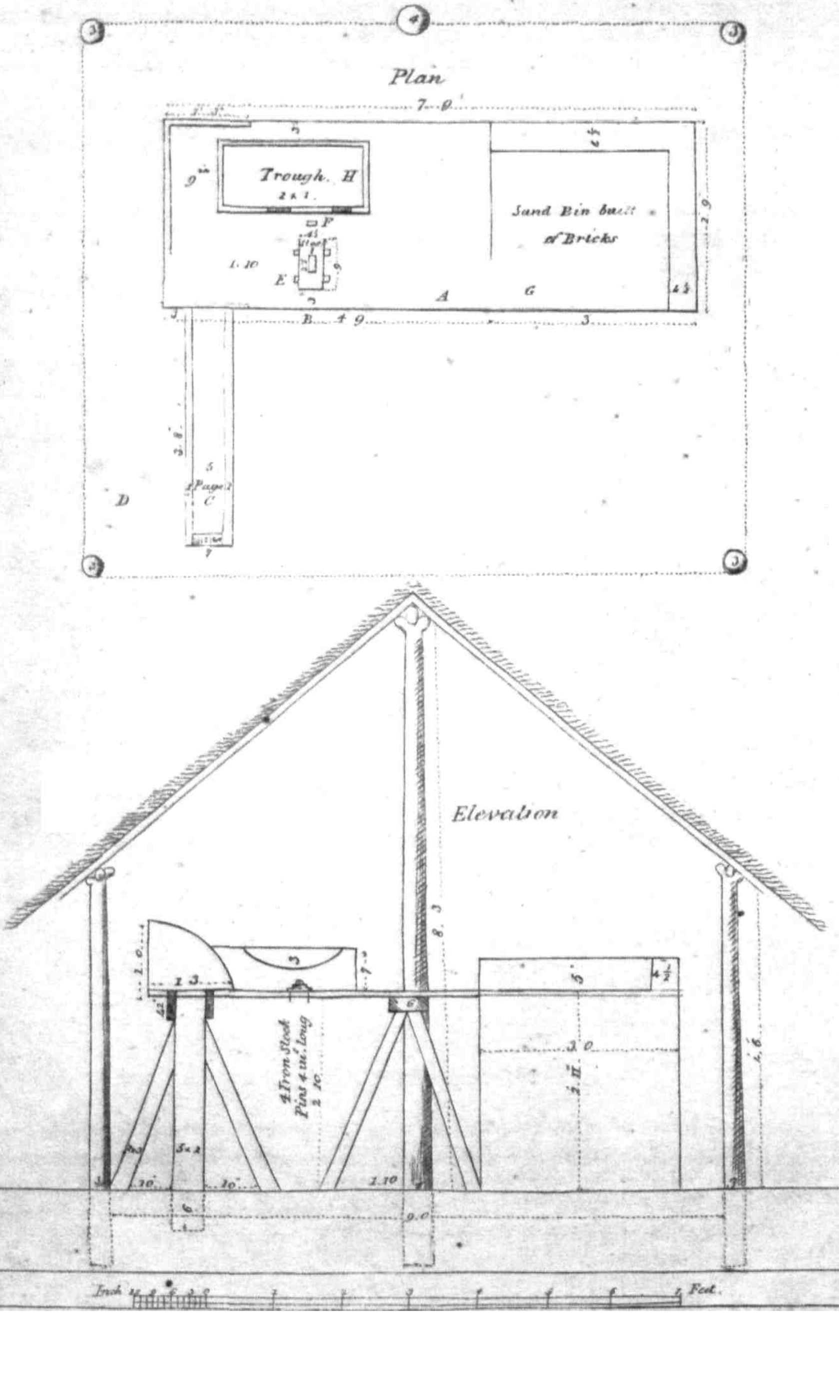
The following is the method of forming the clamps at Madras. A square or rectangular piece of ground, the size of the intended clamp, is levelled and two layers of bricks are laid down in rows, with the space of a brick between each row. Billets of wood are placed in the spaces and also above the bricks to a height of 6 inches. Then comes a course of bricks placed diagonally, above which a thickness of 6 inches of wood is placed; then two courses of bricks on edge, above which, 9 inches of wood. The clamp is then raised to the desired height with one foot of firewood between every four courses of bricks.* As the clamp is being raised its sides are supported by a wall of raw bricks with buttresses at intervals. The object of the wall is partly to prevent the bricks from falling out, as the firewood is consumed, and, partly, to lessen the draught. (See Plate V.)

The bricks are not packed very closely in the clamps. The sides are plastered with clay and the clamp is lighted to windward (straw and brush-wood being used to communicate the flame to the rest of the fuel) and when smoke begins to appear at top, that also is plastered. Should a strong wind be blowing, a screen of mats or cloths is placed on the windward side of the clamp, to lessen the draught; for, if the fire gets too violent, many of the bricks will become distorted by partial fusion, or fuse and adhere together. They are then useless for building purposes but form an excellent road material. The outside bricks of a clamp never get properly burned, but they may be reserved for the outer casing of the next clamp that may be built, and being then turned with their unbaked sides inwards, some of them may become available. It is thought advantageous to make the clamps large, thus, twenty lacs of bricks would be burned in two clamps. Such clamps would take about a week to burn, and three weeks to cool. A clamp containing a lac requires two days to burn, and a week to cool. No clamps should be opened until the bricks are quite cool. It is reckoned that a clamp containing a lac will produce 40,000 well burned bricks, a like number of "second sorts," and 20,000 "third sorts;" but these

* No two clamps are constructed in precisely the same way. An Overseer, who has a large quantity of bricks to prepare, should make his first clamps small, and observe how much firewood is required; he may then proceed with confidence to construct large clamps, containing one or more lacs of bricks.


Native Tile Kiln
Fig 1.
Fig 2.
Section thro A. B.
Section thro C. D.
Fig 3.
Native Brick Kiln
Fig 4.
E
F
Section
Elevation
Fig 5.

PLAN and ELEVATION
of a Brick makers Work Bench



last are great trash, and so indeed are many of the "second sorts." A clamp containing 6½ lacs of raw bricks, lately constructed at Madras, and occupying a space of 57 feet in length, 31 in breadth, and 23 in height, yielded after burning, 5½ lacs of bricks; of these, 4 lacs were well burned, and were divided into first and second sorts; another lac consisted of bricks that were tolerably well burned, and the remaining half lac, though very bad, were purchased by the Natives.

In the other method of constructing the clamps, the fuel consists of larger pieces, chiefly of the tamarind tree, and instead of being placed in layers over the whole surface of the bricks, is placed in passages at intervals. The first plan is found to answer best, as the great heat of the logs causes the bricks round them to run into masses. The amount of loss varies very much, but is generally considerable.

Bratties and horse litter are used in some parts of India for burning bricks.

Brick-Making at Mercara.

Preparation of the earth.—The clay is dug up, cleared of stones, rubbish and vegetable matter, all lumps broken small, and then left in heaps exposed to the action of the weather, and in this state it is desirable that it should remain for a year, before being used for bricks.

Tempering.—After the clay has been left exposed, as abovementioned, and is perfectly broken up, it should be turned over, and again cleared of all impurity, and then tempered in a Pug-mill, which will be described presently.

Gang.—A gang of brick-makers, supposing the clay has been tempered in a Pug-mill, consists of 1, The Moulder; 2, The Wauk boy; 3, The Temperer; 4, The Off-bearer; 5, The Setter off.

Sheds and Benches.—Plate VI represents the moulding-shed and bench; the bench being on trestles, with a solid brick stand at the right hand side, for holding the bin of sand, and the lump of clay as formed ready to mould into a brick.

A, represents this lump of clay, just enough for one brick, and which is put there by the Wauk boy.

B, the place where the moulder stands.

C, the Page on which the new made brick is placed.

D, the position of the off-bearer.

E, the stock, fastened to the bench by screws, on which the mould is placed. The stock is a piece of plank half an inch thick, its length and breadth the same as the interior dimensions of the mould; the blue mark shown on it is a projecting piece of iron, a quarter of an inch high in the centre, sloping off to all four sides, which causes a corresponding cavity in the brick, and is supposed to contribute to strength in building,

as it fills up with mortar. The four pieces of iron shown, two on each side of the stock, are spikes or clamps, which partly serve to keep the stock in position, but their principal use is to prevent the mould when placed on the stock from touching the bench, which enables the moulder the more readily to cant the mould, when he is going to remove the brick. At the close of each day's work, a lump of moist clay should be left on the stock to prevent it warping.

F, is a hole cut in the bench directly behind the stock, 2½ inches by 1½, which is for the superfluous clay cut off by the strike to fall through.

G is the bin of fine sifted sand.

H, a trough of water.

Hacks.—The arrangement and dimensions of the hacks, for drying the bricks, are shown in Plate VIII.

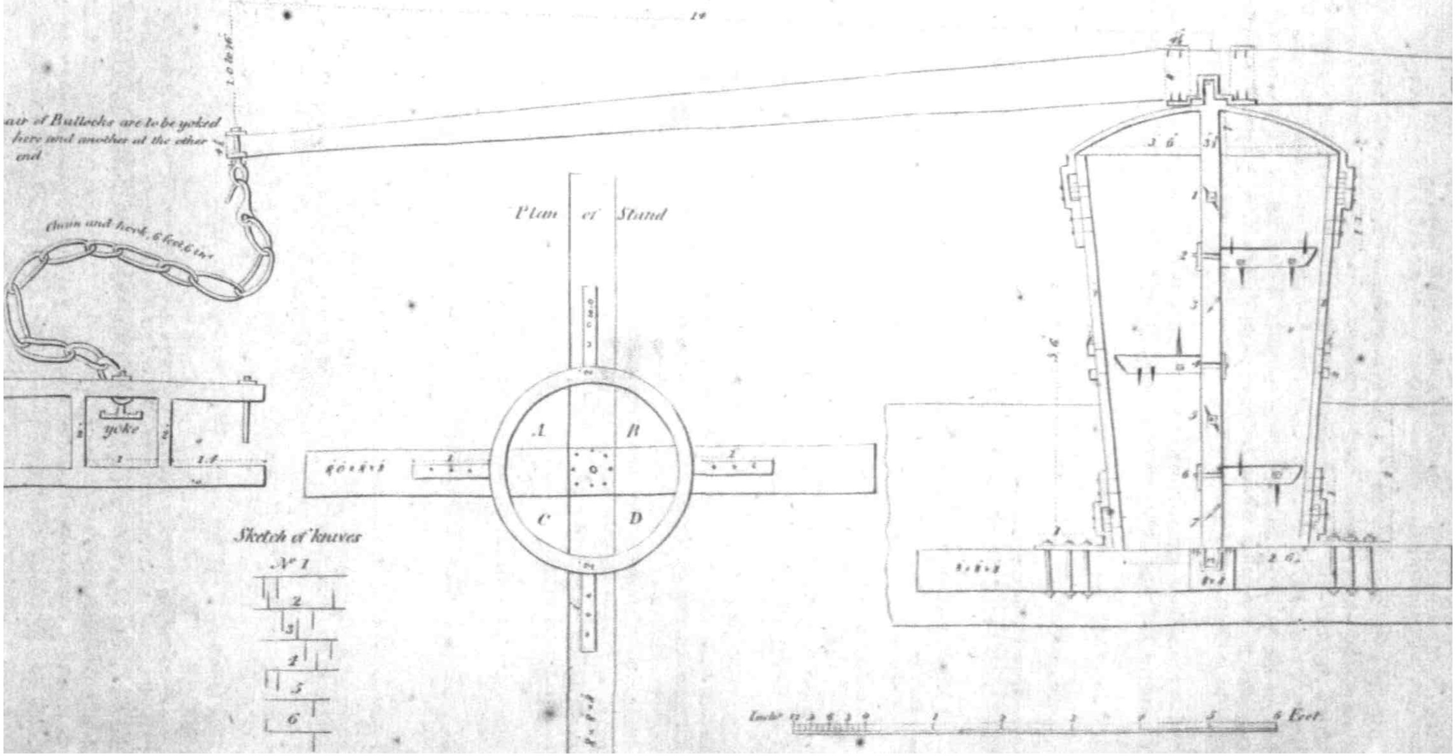
Pug-mill.—In Plate VII, are the plan and sections of a Pug-mill for tempering clay for bricks. The clay is put in at top, and water as required to moisten it, the mill being kept constantly at work. It is turned by bullocks. There are six hoops on the tub, 2 inches wide and half an inch thick. The six top knives are 4 inches wide, and are bolted into the spindle, at an angle of 45°, having teeth let into them: the blades of the teeth are 4 inches long, without the screw and nut which attaches them to the knives. The teeth are fastened to the knives at unequal intervals (see sketch). The seventh, bottom, or shooting knife has no teeth, is 6 inches wide, and let into the spindle at an angle of 55°. The mill must be sunk two feet, to allow of the soil being conveniently thrown in from above, and also to avoid having a raised track for the bullocks. There must be a ramp down to D, and a space excavated there for the mud to come out at, and to allow of its being carried away. A, B and C are permanently built up with bricks; D is only stopped when the mud is first put in, until it is sufficiently prepared for the moulder, when the tamping is withdrawn, and not again replaced while the mill remains in constant daily use.

Sheds over the Hacks.—If the weather is wet or very hot, it is requisite that the hacks, on which the new made bricks are placed, should have small sheds over them. They may be very light and roughly made, costing but little, and the expense will never equal what would otherwise be lost, by the quantity of bricks which would be destroyed by the rain or a hot sun. These sheds are not required over the other hacks, where the bricks are placed when partly dried. It will be sufficient when the bricks are raised the required number of courses, to lay a little straw across the tops, which acts as a temporary thatch, and this need not be done when there is no rain.

Moulding.—No. 3 (temperer) brings the clay to the bench, and puts it down close at hand, when No. 2 takes off just enough to make one brick, forms it into an oblong lump, and lays it down at A. No. 1 then lifts this lump with both hands and throws it smartly into the mould, pressing it down into all the cavities, and with the *strike*, strikes off all superfluous clay. He then slightly sprinkles the top of the brick with sand, and turns

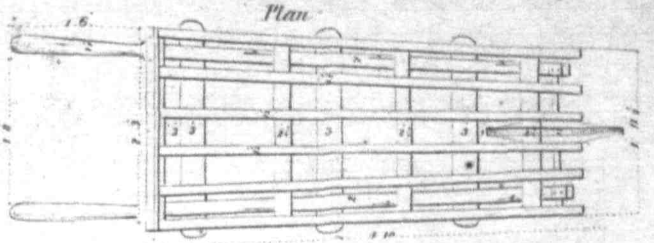
SECTION of a PUGMILL

for the purpose of preparing mud for Brick making.

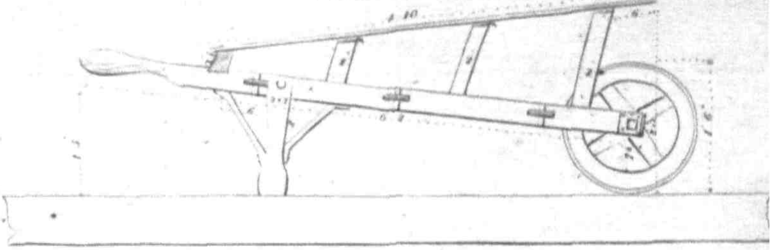


PLAN and SECTION of a Brickmakers Hack Barrow.

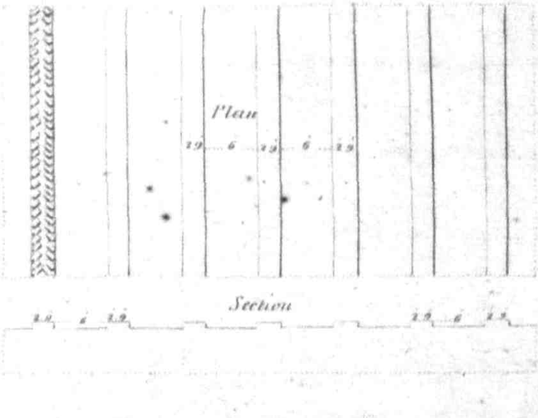
Plan



Elevation.

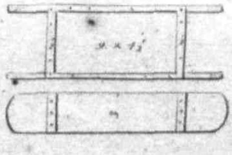


Plan and Section of a portion of Ground laid out in Hacks.

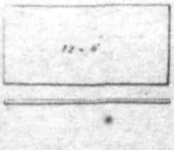


BRICK MAKERS TOOLS

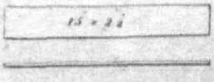
Plan and Elevation of Mould lined with sheet iron



Plan and Section of Pallet Boards

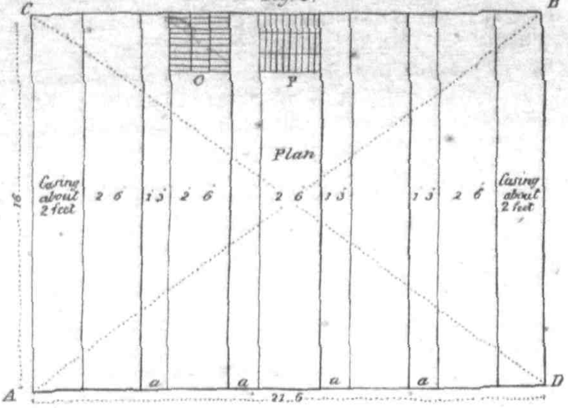


Plan and Section of Strike

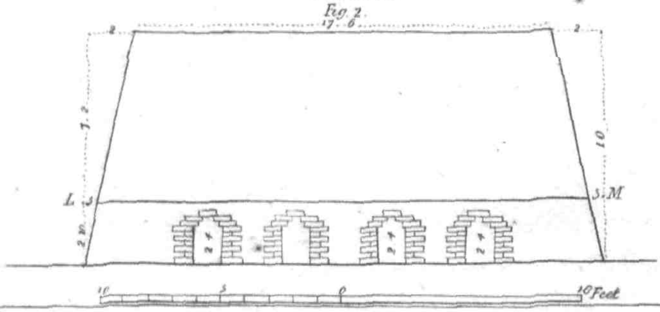


PLAN and SECTION of a BRICK KILN
large enough to Burn 40,000 Bricks

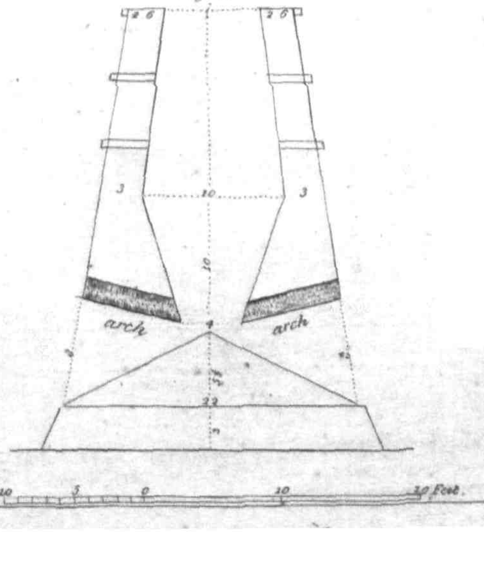
Fig. 1.



SECTION
Fig. 2.



SECTION
of a Chunam kiln
Fig 3



it out on the pallet board, laying the pallet board, with the brick thereon, across the page. In putting the bricks on the page, there must always be ready, at the end of the bench near the page, a number of pallet boards. In turning the brick out on the pallet boards, the moulder smartly cants the mould upwards towards the left, turns to his left, applies the bottom of the mould to one of the pallet boards, and having laid it across the page, gently raises the mould from off the brick, which remains on the pallet board, and is then pushed gently to the other end of the page, to leave room for the succeeding bricks as they are formed. No. 4 shifts the bricks from the page, places them on the off-bearing barrow, and wheels them to the hacks very gently, when they are taken off the barrow by No. 5; No. 4 in the mean time going back to the bench with another barrow.

In laying the bricks on the hack, a second pallet board is placed on the top of each, and the brick being taken up between the two is laid on edge on the hack; the boards being gently raised up as soon as the brick is put down. The bricks are laid across the hack and no interval left between each two, except a trifle more than the thickness of the pallet board, and at this stage of the process, there is only one course of bricks on each hack. When sufficiently dry to bear handling without losing shape, they must be removed to other and more distant hacks in the vicinity of the kiln, to complete the drying, and are placed as shown in the plate. On the top of the first course another is placed, the bricks being at right angles to the direction they bear in the first course, and so continued alternately for about ten courses. They are left open on the hacks, to allow the wind to pass freely and dry them, and here they must remain until perfectly dry, which can be ascertained by taking a few indiscriminately and breaking them.

The mould should be dipped in sand after each brick is turned out of it, to prevent the clay adhering to it, when moulding the next brick. The *strike* must always be kept clean and wet by constantly dipping it in the trough of water.

A smart man, after two months practise, can mould 1,200 bricks in 6½ or 7 hours. In stacking the bricks on the hacks, a man can stack 200 in a day of 6½ hours. If there is no pug-mill, one man can temper clay in 6½ hours for 500 or 600 bricks.

Kiln.—In Plate IX, *a a a a*, are flues, that run right through the kiln, and are open at each end. In all the spaces between the flues, bricks are laid end to end as shown at O; immediately over that course, another is laid as shown at P, and so on alternately, until they are the required height; the upper three meeting gradually over the flues (see section). The bricks are to be laid on edge. In these walls of the flues, the bricks are kept a little apart, but above the line LM they are packed quite close. They need not, however, be packed, all through to the top of the kiln, in courses at right angles parallel to the sides. It is better to have some courses in the direction AB and CD alternately (see plan).

Firewood.—The best kind is logs, 5 feet long or less, and from 8 to 16 inches in diameter. Each log to be split into three or four pieces.

Fire.—A slow fire should be kept up for 12 hours after lighting, and then the heat should be increased by keeping up a smart fire for about 36 hours, when the flues should be closed and the fire allowed to die out. One and a quarter country cart loads, say 900lbs. weight, of wood, are sufficient to burn 1,000 bricks. Average weight of a kiln of burnt brick (9″ × 4″ × 2″ to 2½″) is 5lbs. 4 ounces.

Miscellaneous Remarks on Brick-making.

Cost of Bricks.—The cost of bricks depends principally on that of firewood. The bricks used in building a large bridge over the Cauvery in Coorg, were delivered on the work at the rate of one rupee a thousand: the firewood there was close at hand, and cost nothing but for cutting down. Some bricks made for the Godavery annicut, cost 5 annas and 10 pice a thousand for tempering and moulding, and 3½ annas for piling, plastering and firing; this was exclusive of the cost of firewood, (4 annas per 1,000lbs.) the quantity allowed of which was nominally 1lb. for each brick. The cooly hire was 1½ annas a day. At Bangalore, the "first sort" bricks cost 2½ rupees a thousand, and "second sorts" (very inferior to the former) 1⅞ rupees. At Trichinopoly, the prices are 3¼ and 2½ rupees respectively. At Madras, about 1,400 bricks (first and second sorts) can be purchased for 3½ rupees and about 2,200 of the third sort for the same sum.* Really good bricks could not be sold at these rates. In burning a large clamp of bricks lately at Madras, a large bandy load of wood, costing 3 rupees, was used for 2,000 bricks. Tempering and moulding the bricks cost 2½ annas a thousand; packing in the clamp, plastering, &c., 2 annas a thousand. A man and woman can temper and mould 1,500 bricks in a day; if, however, the tempering were performed as it should be, the number would not be so great. A man can mould 1,200 bricks in a day, if the tempered earth is brought to him.

Bricks are almost always made by contract, and for the numerous petty irrigation and other works, they could not be procured in any other way. A stock of bricks is rarely kept in any village; when any are wanted for a work, an advance of money is necessary to allow of their being made. For large works also, the bricks are generally made by contract, but they might often be made better and cheaper under the superintendence of an overseer who understood the business. The contractors rarely know anything about the matter, and they pay their coolies too little to allow of the earth being properly tempered, or the other operations being carried on with sufficient care. Firewood should be furnished to them, or they will make the difficulty of procuring it an excuse for delay in furnishing bricks, especially towards the end of the season, when every effort is required to complete the work before the monsoon, or at least to bring it to a certain stage. They then point to the heaps of half burned bricks which were rejected at the commencement of the season, and insist on these being purchased before they will furnish any others,

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* The price of bricks is always higher in large stations than in villages, for wood is scarcer and generally wages are higher.

and, as they have usually received large advances of money, they are enabled at this time to be very troublesome.

Moulds of the proper size ought to be given to the contractor, and they should be examined from time to time, and when found to be worn much, their place should be supplied by new ones.

A bandy load of bricks consists of about 400, on a good road; the number conveyed in a day by each bandy will, of course, depend on the distance of the clamps from the work.

Size of Bricks.—It is very desirable that there should be some fixed dimensions for bricks, in order that the number required for, or contained in, any particular work may be readily calculated. A law determining the size would impose no hardship on the maker and would prove a convenience to the purchaser. Whatever may be done in the matter of bricks made for private use, it seems a pity that those required for public works are not made by some fixed standard. Of late years, in some of the Collectorates, bricks measuring 9 inches in length, 4½ in breadth, and 2¼ in depth have been made for public works, and are called by the Natives "Company's bricks." The dimensions are not good, and the following are recommended in their place: length 8¾ inches, breadth 4¼, and depth 2. Each brick, with the quarter-inch mortar joint, will then occupy a space of $9 \times 4\frac{1}{2} \times 2\frac{1}{4}$. It is of importance that the length should exceed twice the breadth by the thickness of the mortar joint, as will be shown in another chapter, but the thickness need not bear any definite proportion to the length and breadth. Bricks three inches thick, provided they could be equally well burned, would be preferable to those only two inches thick, as a much smaller number of them would be required, and the joints being fewer, the less would be the amount of settlement.* It is said that the thick bricks are not so easily broken, on their way from the kilns to the work, and this is a great recommendation in their favor. *Paving bricks* should be $8\frac{3}{4} \times 8\frac{3}{4} \times 2$. They are now made 6, 8, 10 and 12 inches square; but there is no necessity for more than one kind being made. *Terrace bricks* should be $5 \times 3 \times 1$. *Arch bricks* are usually made $10 \times 5 \times 1\frac{1}{2}$; but there is no occasion for their dimensions differing from those of wall bricks, except when they are moulded (wedge-shaped) expressly for an arch. Bricks for round pillars are made quadrant-shaped, and their size, of course, depends on the diameter of the pillar. *Well bricks* are made somewhat narrower at one end than at the other; the difference depends on the size of the well for which they are intended.

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* The economy in using thick bricks will be seen by the following calculation. A brick measuring with its mortar joint $9 \times 4\frac{1}{2} \times 2\frac{1}{4}$ contains 91⅛ cubic inches; another measuring $9 \times 4\frac{1}{2} \times 3\frac{1}{4}$, contains 131⅝ cubic inches. A cubic foot, or 1,728 cubic inches, will require above 18 of the former, and only 13 of the latter—being a difference of 5. Now, a large annicut of bridge may contain 200,000 cubic feet of brickwork and the difference on that quantity would be 10 lacs. But besides this, less chunam would be used with the thick bricks, as the mortar joints would be fewer, and again, as a bricklayer can lay in a day as many thick bricks as he can thin bricks, so a further saving in workmen would be effected by the use of the former.

Of Tiles.

The manufacture of tiles in England, though everywhere similar in principle, is more or less modified in its details, according to the locality, and those who are desirous of making themselves acquainted with some of the varied methods, there pursued, will find much useful information, at a trifling cost, in " Dobson's *Rudimentary Treatise on the Manufacture of Bricks and Tiles*," published by Weale. But, as it may, perhaps, be deemed more desirable to know what may be and has been effected in Southern India, in the art, a detailed account is here given of the process pursued at the Head Quarters' Depôt of the Sappers and Miners at Mercara.

Tile-Making at Mercara.

The manufacture of Tiles at Mercara is confined, as it is in most parts of India, to three descriptions of roofing tiles, viz. : the pot tile, the pan tile, and the flat tile. Gutter and ridge tiles being merely a larger description of the two first.

The pot tile.—Pot tiles are formed on the wheel and as the process may be seen in every Native village where chatties are manufactured, and as yet no great improvement on the Native process has been made at the Mercara Depôt, more attention having been given in preference to the other two kinds, any detailed description of the process is unnecessary; and it may only be observed, that the Natives appear capable of making a better kind of tile in this way, than when moulding, insomuch as they require to use a much stiffer clay than in making flat or pan tiles, and both temper and work the clay into a superior substance. The shape, however, of the pot tile is a disadvantage,* as, from having no mould to form it to a uniform size, it is impossible to adhere to any fixed gauge or overlap in roofing with them, which, besides being unsightly, is a great drawback in a wet climate such as that of Mercara, Cannanore and other stations on the Western Coast, where a double course is requisite to keep out the rain; and if the tiles be not of a really superior kind, (a matter very difficult to secure when a large quantity, in a limited time, is required) the superincumbent weight of the upper course, when wet, is very apt to break large numbers of the lower one, and this very often renders the double course less water-proof than a single course might have been.

The pan tile—is in shape similar to the pot tile, differing from it only in being shorter, heavier and less curved. As made by the Native contractors, it is also of very inferior material, but, as only one kind of clay is used at the Mercara Depôt for both the pot and pan tile, and equal care is taken in tempering and manipulating it in both cases, an equally good tile, as regards quality, is obtained by moulding as in turning on the wheel, with the further advantage of having them of a uniform size. In the manufacture of tiles, as in bricks, the quality of the ware depends chiefly on three particulars, viz. : the nature of the clay—tempering—and burning.

These three points once thoroughly understood, the manufacture is

* The disadvantage is one which may be overcome, most probably, after some experimental trials, and such it is hoped may ere long be made.

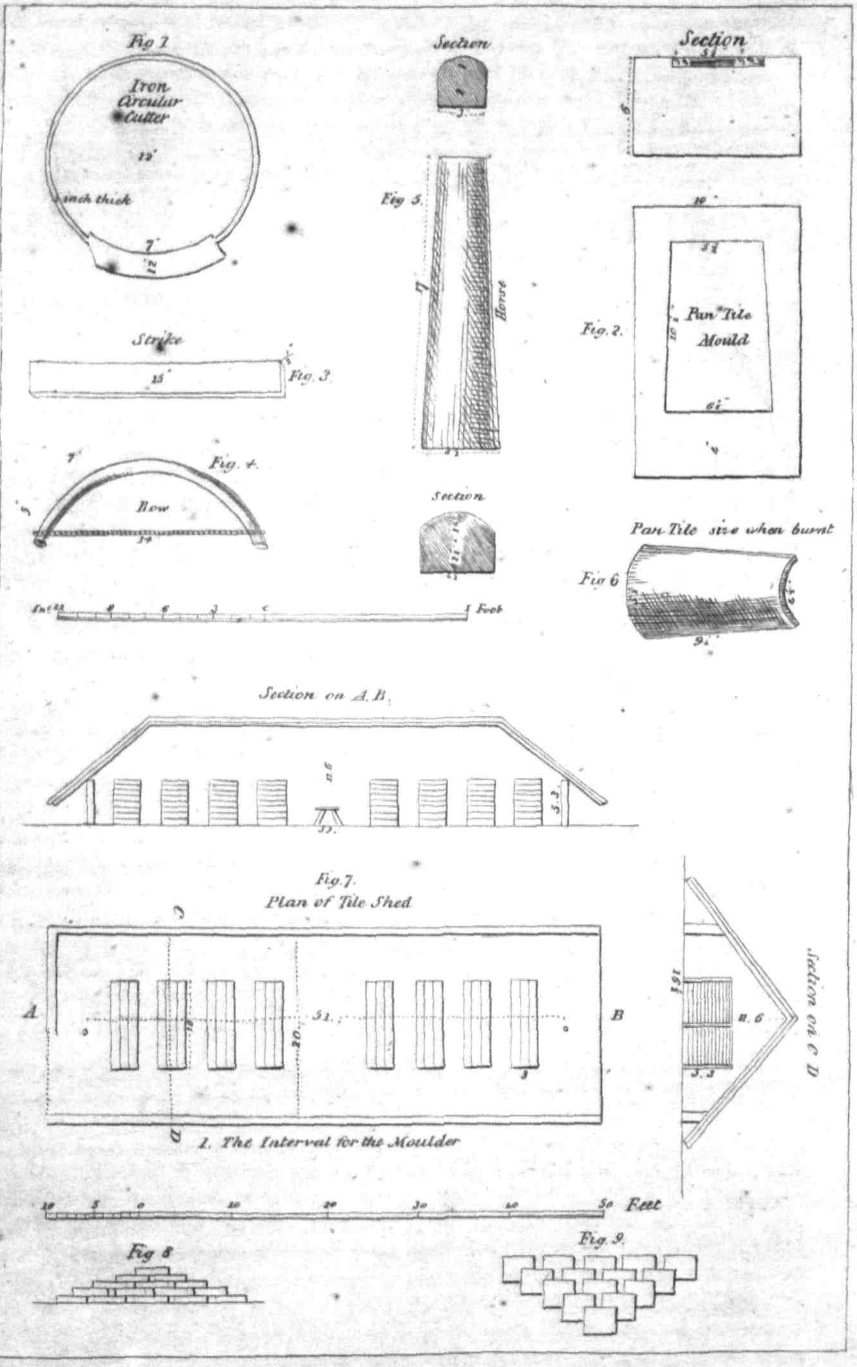

Fig 1
Iron Circular Cutter
inch thick
Section
Fig 5.
Horse
Section
Fig. 2.
Pan Tile Mould
Strike
Fig. 3.
Fig. 4.
Bow
Section
Pan Tile size when burnt
Fig 6
Feet
Section on A.B.
Fig. 7.
Plan of Tile Shed
A
B
C
D
1. The Interval for the Moulder
Section on C D
Feet
Fig 8
Fig. 9.

comparatively easy—they may to a certain extent be described, but practise alone can afford the requisite knowledge, and any one, therefore, who, with a mere written essay as his guide, makes a first attempt at improving Native manufacture, must be prepared for some disappointment before he is likely to arrive at a successful result.

The process of manufacturing this description of tile is as follows:

Clay getting and weathering.—The clay used is of a blackish color and very stiff, generally found underlying the brick earth, from 5 to 10 feet below the surface of the ground, in the vicinity of paddy or marsh lands. It is stiff enough to require a little sprinkling of the brick loam immediately overlying it, or else of sand, the proportion of loam to clay varying with the quality of the latter which experience can alone determine.

The clay is usually *uncallowed* and dug out, immediately before the rains, and spread in heaps, in which state it is allowed to remain during the four or five monsoon months, with the view to break down the harder and knotty pieces, so as to render them easier worked; but as it is found in England, that wet retards the process of weathering, while hot dry weather or frost is beneficial, this practise may be deemed questionable, until some direct experiments have been made to determine its advantage or otherwise.

Tempering.—After the rains cease, the clay is put into tempering pits, about one foot deep of any convenient area, and the bottom paved with bricks, where it is covered entirely with water for about twenty-four hours, when a little more water is thrown over it. At the expiration of about twelve hours after this, the clay is trodden by men's feet, for two or three hours, which completes the first course of tempering. It is then removed into sheds, by the same people who tread it, and is there formed into conical plaster heaps about four feet high. These heaps are cut, or rather pared down in thin slices from top to bottom, with a circular iron cutter (Pl. X, Fig. 1) which process is repeated three or more times, until the hard pieces and stones have been broken down and cleared, and the mixture of clay and loam well amalgamated. It is then well worked and kneaded with the feet on hides or boards into a stiff paste, every hard substance which the eye or feet detect being removed, when it is in a fit state for the potter or moulder.

For making pan tiles, a gang of three people only is required, viz.:—1, Temperer, (man)—2, Moulder, (man)—3, Cleaner, (boy or woman).

Temperer.—The temperer's duty is simply to prepare the clay, in the way above described, for effecting which, all he requires is a mamooty or spade, a chatty and a basket, and to carry and place the clay in heaps by the side of the moulder. Water is supposed to be sufficiently at hand to allow of the temperer fetching it himself.

Moulder.—The moulder sits on the ground with his *mould*, (Fig. 2) *water trough* and *strike* (Fig. 3) in front, and after covering his mould with wood ashes, or finely sifted brick dust, previously deposited near him, he takes off with his hands a piece of clay, more than sufficient to

fill the mould, which, after roughly shaping, he throws into the mould with all his force, taking care to work it well into the corners and other parts, and then cuts off the superfluous clay with the bow, (Fig. 4) made of wire or string stretched on any elastic piece of wood. He then presses his strike, a flat piece of wood, or ruler 15 inches long, 2 or 3 broad and half an inch thick (Fig. 3) backwards and forwards over the clay, till the surface is tolerably smooth and level with the upper surface of the mould, after which, opening the thumb and fingers of his left hand, he presses the hand thus extended slightly *on to the clay in the mould*, which, adhering to the palm and fingers, is easily lifted out and placed on a burnt pan tile near him. Each succeeding piece thus taken out is placed on the top of the previous one, until a heap of twenty is collected, when a new heap is begun, and so on. The heaps are left till the following day to dry a little,* when the moulder shapes them into the curved form, on the convex back of a *horse* (Fig. 5), by simply bending them gently over it and smoothing the back of the tile itself with his hand dipped in water. The horse, having been previously well sprinkled with wood ashes or brick dust, permits the tile to be easily taken off it, which the moulder does with both hands and then places it gently on the ground, (which ought to be well rammed and flattened) until one heap of twenty is finished; he then proceeds to another heap, and so on. In this way, an experienced moulder will mould and horse 300 per diem. After lying on the ground five or six hours, or till sufficiently stiff to be handled, the tiles are taken up and re-horsed by a man or boy called the *cleaner* or *washer-off*.

Cleaner or Washer-off.—This individual trims the edges with a knife, clears away the ashes from the interior, by rubbing it lightly over with grass and afterwards washes it with his hand well wetted, rubbing it over till quite smooth. On completing this process, he lays the tile again on the ground where it is left for eight or ten hours, until it is *hand-hard*, that is, stiff enough to be placed carefully on its narrowest edge against a board or wall; when they are all picked up and disposed of in this way, that is, standing out at right angles to the wall one over another and so left until quite ready for burning.

Burning.—The burning is effected entirely with wood, which is mostly green, as it is seldom cut before it is required. The *kiln* (Plate XII) is circular, and of size sufficient to burn 30,000 tiles at a time. As in the case of bricks, the fires must be gentle at first, until the disappearance of all white steam; after this, they may be gradually raised to a greater heat, until the inside of the flues appear red hot; the fire is then slackened for six hours, after which, it is again raised till the interior of the flues has been brought to a white heat, and kept so for about three hours. The fire is then again slackened for six hours, putting in no more wood during that time. At the expiration of the six hours, the fire is raised to the same heat as before and kept up for about four hours, when the flues are quite filled with fuel, and their mouths stopped up with brick and mud, the fires being allowed to go gradually out. The

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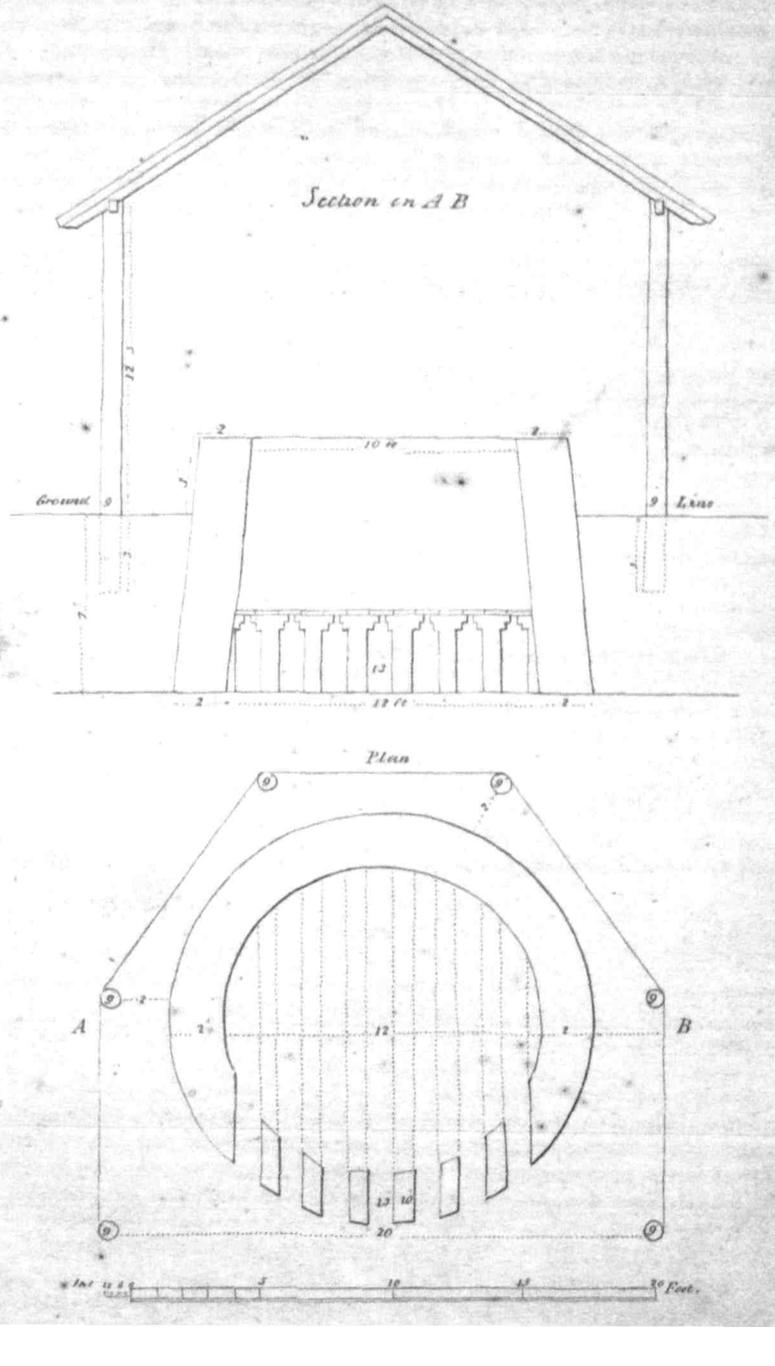
* The time for drying must, of course, vary with the nature of the climate and all that is requisite to be careful of on this score, is that the clay is sufficiently plastic to be bent without cracking.

PLAN and SECTION of a TILE KILN



burning generally takes 72 hours, being maintained night and day. In windy weather, the kiln should be sheltered as much as possible on the weather side, otherwise, a large number of the tiles on that side will be found underburnt: these are technically termed *burn-overs*, and should be on the top of the next kiln to be fully burnt. In setting the kiln, a flooring is first made by a course of bricks laid flat and somewhat open, over the tops of the flues, and on this flooring the tiles are stacked as closely as they will lie on edge, course upon course. When the kiln is full, the doorways* or hatches are bricked up, and the top covered with a course of old tiles laid loosely over it.

Cost.—To make a kiln of 30,000 pan tiles, the following labor and materials are required, the cost of which will vary, of course, according to the price of the station:

			RS.	A.	P.
Digging out clay† ...			3	8	0
Tempering and removing to spot,	100 men at 2 annas...		12	8	0
Moulding...	... 100 men at 4	,, ...	25	0	0
Cleaning ...	... 100 boys at 1⅓	,, ...	8	5	4
Stacking ...	... 15 men at 2	,, ...	1	14	0
Burning and watching	... 18 men at 2	,, ...	2	4	0
27 Country carts' load of wood ...	... 8	,, ...	13	8	0
		Total...	66	15	4

Say 67 Rupees the kiln, which will be about 2¼ Rupees per 1,000. The prices given are those of Mercara, and are exclusive of the original cost of the kiln, which, once properly constructed of brick in clay, will last the whole season and with repairs for two or three years. The cost of tools and sheds for moulding and drying is also extra.

Sheds.—It is necessary to have sheds, as, owing to the stiffness of the clay, the tiles, on exposure to the wind and sun, except for a very short time, crack and get out of shape very extensively. As the Natives never go to the expense of constructing such sheds, they are obliged to use a very mild clay, to prevent this loss, so that it is no wonder their tiles are of such inferior description.

It is a good plan, to gain room in these sheds for moulding, to have a series of blocks or drying shelves, which are formed with 3 inch planks, placed 4½ inches one above another, on bricks laid on edge, and carried to any convenient height above the floor. The size of the shed and number of these blocks will depend on the number of moulders at work, but the area allowed to each is 16 feet long by 20 feet wide, and the moulders should be so arranged as to leave a passage of about 3 feet all

* The doorway is not shown in the plan; it is merely an opening two are three feet wide in any convenient part of the wall, above ground, for the purpose of filling and unloading the kiln.

† One cubic yard of clay, well tamped and tempered, will make about 1,060 pan tiles, 10½ inches by 6½ by ½.

around the blocks, so as to have them easily accessible. The moulders sit either in the centre or at the side of the shed, and the blocks are placed all down the centre (Pl. X, Fig. 7). The blocks should have nine tiers of planking.

The loss in making and burning depends on so many contingencies, varying with the season, that no correct average can be given. It should, however, certainly be under 10 per cent.

Method of making flat tiles.—The clay-getting weathering and tempering, being precisely the same as for pan tiles, need no further description.

In making flat tiles, a gang of five people is required, viz. :—

1 Moulder, (man) ;

1 Temperer, (man) ;

1 Clot moulder, (woman or boy) ;

1 Bearing-off boy, (boy) ;

1 Trimmer, (woman or boy).

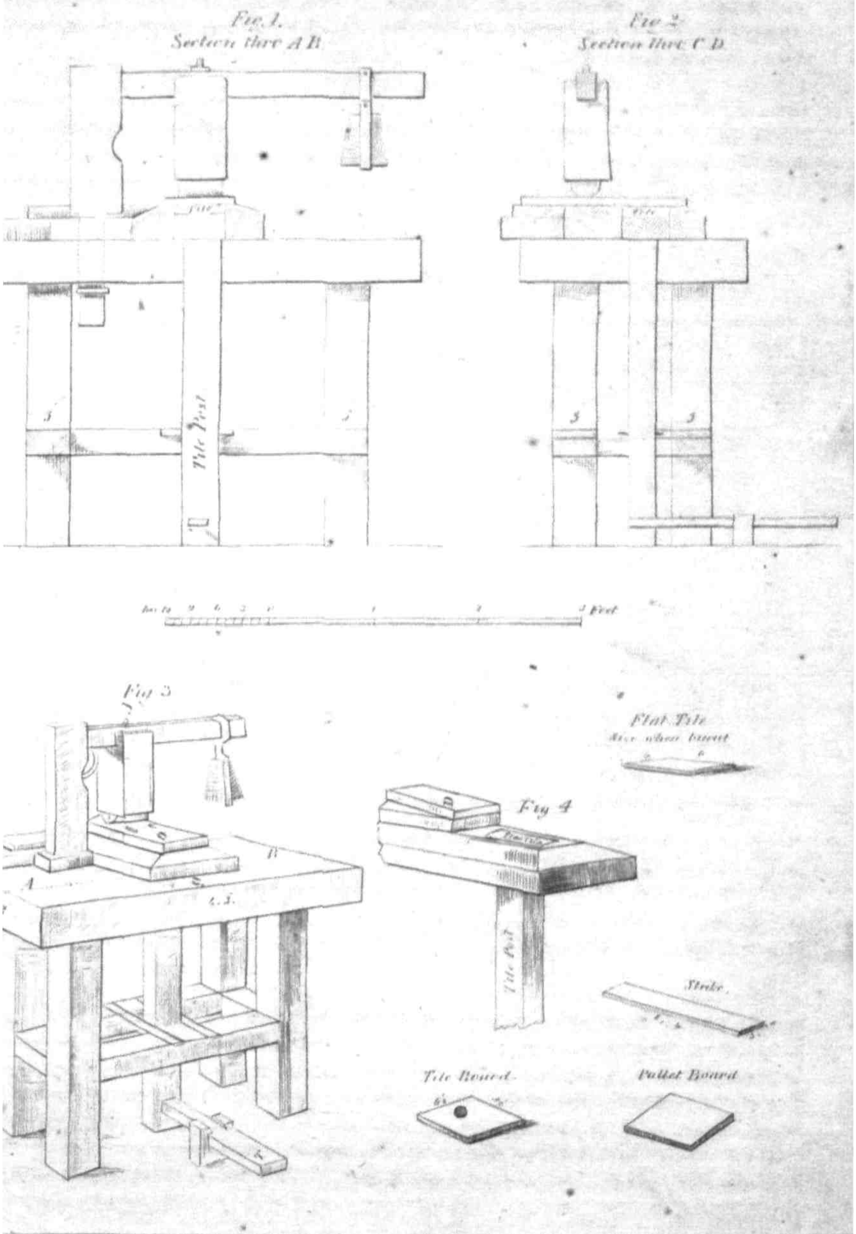
Temperer.—It is this man's duty to temper the clay, in the mode already described, after which, he squares up a piece of it into size, thicker than the mould but smaller in the sides, a habit he acquires after a little practise. This is called a *half piece,* and should be thick enough to make ten or twelve tiles—this he hands to the

Clot moulder,—who, being furnished with the bow formerly described, takes the half piece, and placing it at one end, cuts off a slice which she puts on a pallet board, well covered over with fine wood ashes, and patting it with her hand, forms it into the shape of a rough tile called a clot, which she passes to the moulder standing on her left.

Moulder.—The moulder, with his mould fixed on the table in his front (Pl. XI, Fig. 3) and well sprinkled with wood ashes or brick dust, takes the clot, and putting it into the mould, at the bottom of which a tile board also covered with ashes has been placed, gives the clot a few sharp taps with the palm of his hand, then turning down the moveable top D (Fig. 4) of the mould on to the clot, he draws the lever and weight forcibly towards him, until it presses hard on the top of the mould, which is effected by three friction rollers fixed into the bottom of the lever post. With his right foot he then gives the treadle T (Fig. 3) two or three smart jerks, which tends to press the clay well into all parts of the mould ; and, afterwards, throws back the lever and weight, raises the top of the mould, and with a wet strike, of the same kind as before described, cuts off the surplus clay ; after this, he gently works his wet hand over the top surface of the tile, a pallet board well covered with wood ashes being then placed on the top, the moulder, with one jerk of the treadle, forces out the tile and board on which it rests, ready for the

Bearing-off boy,—who stands directly opposite to him, on the other side of the moulding table, and whose duty it is to keep the pallet and tile boards well covered with wood ashes, and to seize and carry off the newly formed tiles, and place them on the blocks to dry. This he

FLAT-TILE MACHINE



does by catching the pallet and tile boards, with the tile between them, gently with both hands; he then reverses the boards by turning them dexterously over, with the tile still between them, thus bringing the tile board uppermost, which, by means of an iron fixed eye in its bottom, he removes easily with his right hand, leaving the tile resting on the pallet board, lying on the palm of his left hand. The tile board he places on the moulding table, ready for the moulder to put in the mould again, and then carries off the tile to the blocks or in their absence to a *flat*, a piece of ground duly prepared with rammers and *chany** to receive it—here it is left till *hand-hard*, when it is removed by the *Trimmer-off*, whose business is to gather up all these *hand-hard* tiles and place them in heaps of ten or twelve. He then trims the rough edges with a knife, places them one at a time between two flat boards, which he presses together with his hands, and rectifying anything he finds wrong in the shape, he then places them in rows, as in Fig. 8, piled one on another, where they are left till quite dry, after which they are carried to the kiln and stacked as shown in Fig. 9.

Burning.—Kilning and burning, being precisely the same as for pan tiles, need no description, only it may be observed that the flat tiles being of smaller dimensions ($6\frac{1}{2} \times 5\frac{1}{2} \times \frac{5}{8}$ inches) the kiln previously described will hold 50,000 of them—both kinds of tiles, however, are generally burnt together in the same kiln, pan tiles at bottom and flat tiles at top.

An experienced moulder with his assistants will mould 500 per diem.

The cost of labour, &c., for 50,000 flat tiles is as follows:—

				RS.	A.	P.
Clay† digging and removing, at 1 anna per cubic yard...				1	7	0
Tempering	100 men	at 2	Annas...	12	8	0
Moulding	100 men	at 4	,, ...	25	0	0
Clot moulding... ...	100 women	at $1\frac{1}{3}$	,, ...	8	5	4
Bearing-off	100 boys	at $1\frac{1}{3}$	,, ...	8	5	4
Trimming	100 boys	at $1\frac{1}{3}$	,, ...	8	5	4
Stacking or setting kiln	25 men	at 2	,, ...	3	2	0
Burning	18 men	at 2	,, ...	2	4	0
27 loads of firewood ...		at 8	,, ...	2	4	0
			Total...	82	13	0

The cost in this instance, as in pan tiles, is exclusive of kiln, moulding sheds, and tools.

It is, perhaps, scarcely necessary to observe that sheds for moulding and drying are equally required in this case, as for pan tile making—these need no description.

* Cowdung diluted with water.

† A cubic yard of clay well rammed and tempered will make 2,180 flat tiles $5\frac{1}{2} \times 6\frac{1}{2} \times \frac{5}{8}$ inches.

Tile-Making at Madras.

The Native method of making tiles differs from that practised at Mercara, only in the various processes being performed with less care, and in there being no machine for moulding or sheds for drying the tiles.

The same earth is used for making tiles as for making bricks, but it is sometimes mixed with a small quantity of wood ashes. The tempering is performed with more care and less water is mixed with the earth. The same imperfect tempering which produces a brick, though a bad one, would not answer for tiles at all.

The tiles are moulded in the open air and left to dry on the ground. Two days are usually allowed for drying. When working for the contractors, the coolies get 8 Annas a thousand for pan tiles and 6 Annas a thousand for flat tiles, sun-dried. A man can mould a thousand a day of the former and 1,500 a day of the latter. One rupee is usually given for tempered earth sufficient for 20,000 tiles.

Tiles are burned in small cylindrical heaps, also in potters' kilns, which consist of two walls of brick in mud or simply of mud, of various lengths, 6 or 7 feet in height at one end and 3 at the other; their distance apart at one end being about 20 feet and at the other, about 3 feet. The floor of the kilns is generally inclined at an angle of about 30°, the narrow end being at the bottom of the sloping mound of earth on which the kiln is constructed. The kiln in Plate V would contain about a lac of tiles and terrace bricks, with a small proportion of paving bricks, for the three are usually burnt together at Madras. The fuel consists of smaller pieces of wood than are used in the brick clamps with a mixture of bratties and straw, and is arranged in alternate layers with the tiles, much in the same way as in constructing the clamps. Before lighting the kiln, the ends are built up and the top plastered with clay, and sometimes a layer of ashes is placed over the clay. The fire is applied at the lower end. The quantity of fuel for a lac of tiles is about 5,000 billets of wood two inches square and two and a half feet long, 14,000 bratties and two bandy loads of straw. The time of burning is from 10 to 20 days, but some of the tiles are often removed and sold before the burning of the entire kiln is completed.

Pot tiles are not made in the neighbourhood of Madras. The pan tiles are from 7½ to 9 inches in length. Of flat tiles, two kinds are made—thick and thin. The former are about 6 inches in length, 4 in breadth, and three-quarters of an inch in thickness. The latter are from 6 to 6½ inches in length, 5 to 5½ in breadth, and three-eighths of an inch in thickness. It would be better to make but one kind 6 inches square and half an inch thick. The pan tiles should not be less than 9 inches in length, and they would be better if an inch or two longer; they are often moulded flatter than they ought to be.

A bandy load consists of from 1,000 to 1,200 flat tiles and of about 1,000 pan tiles.

The price of tiles at Madras is as follows: Pan tiles, 1,700 per pagoda. Thick flat tiles, thin flat tiles and terrace bricks, 2,000 per pagoda.

SECTION 2.—Mortar, Cements, Plaster, &c.

Mortar or Chunam.*—The ingredients that usually enter into the composition of mortar, are *slaked lime* and *sand*, to which sufficient water is added, to bring the mixture to a proper consistence or temper, before using it for the purposes to which it is to be applied.

It is only the carbonate of lime or mixture of lime and carbonic acid, that is fit for the purpose of making mortar, and this is found in abundance in most parts of India, sometimes in large masses and sometimes in small nodules. The shells of oysters and other fish consist almost exclusively of carbonate of lime. The shells generally used at Madras are fossil shells, and are found in extensive beds, at a few feet below the surface, on the banks of the Pulicat lake and other low marshy places on the sea coast, which are covered by the sea at high water. When lime stones or shells are submitted to a high temperature for some length of time, the water and nearly all the carbonic acid which enter into their composition are driven off, and the result obtained is *quick lime*. The substance, in its new state, shows a strong avidity for water and for carbonic acid, which it absorbs from the atmosphere, and when water is poured over the stone, it swells and cracks, evolving a very considerable degree of heat, and finally falls into a fine white powder, in which state it is denominated *slaked lime* also *hydrate of lime*. Pure limes slake perfectly, but the impure limes, which are often the best for building purposes, do not do so.

Lime is divided into two classes :—1, Common lime; 2, Hydraulic of water lime. The mortar of common lime will not harden under water or in very moist places; hydraulic lime yields a mortar which sets readily, and soon becomes nearly as hard as stone in moist as well as in dry situations. The following is a simple method of ascertaining the properties of a lime stone.† A small portion of the stone to be tried should be calcined over a common fire, on a plate of iron, and afterwards slaked, kneaded into a thick paste and made into a ball, which being placed at the bottom of a glass vessel and carefully covered with water will, in a short time, give evidence of the quality of the stone. If, after several days, it is found not to have set, the stone may be pronounced as affording common lime; but if it has become firmer or hard, it may be classed among the hydraulic varieties and its excellence will be shown by the quickness with which it hardens.‡ These petty experiments, however, are often deceptive; the

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* Chunam is properly lime, but the term is often applied indiscriminately to both lime and mortar.

† To ascertain whether a stone is a lime stone or not—dissolve a small portion of the suspected lime stone in a weak solution of nitric acid and, after all effervescence has ceased, add a little ammonia and then a few drops of the oxalate of ammonia. If a white precipitate (the oxalate of lime) immediately or almost immediately falls, there is no doubt it is a lime stone. All the carbonates of lime effervesce when touched with sulphuric or muriatic acid.

‡ The following is another method of ascertaining whether a lime is hydraulic and in what degree it is so. Make several balls of the hydrate of lime paste, about the size of pigeons' eggs; place them in a basin of distilled water and leave them there for four or five hours or even twelve hours. Take them out and test some of the water with a few drops of the oxalate of ammonia; if no precipitate take place, even after some time, the lime may be pronounced eminently hydraulic, and if there be a precipitate, then inversely in proportion to its quantity is the lime hydraulic.

construction of large works affords excellent opportunities for testing lime stones and they should not be neglected.

Lime Kilns.—The kilns in which the operation of burning is performed are of various shapes and sizes. The kilns generally used at Madras are calculated to hold altogether 75 parahs, that is, 50 of shells and 25 of charcoal,* and their form and dimensions are shewn in Plate XIII. A small arch, one foot three inches in height, the same in breadth, and raised five feet above the surface of the ground, runs longitudinally through the kiln; the top of this arch has a grating of brick on edge, which is partially covered with broken tiles, so that neither the shells nor, charcoal can drop through them, but small apertures are left for the escape of the ashes and for the necessary circulation of air. Over this bed, a layer of charcoal is first placed throughout, about three inches in thickness, and fire applied. When it is sufficiently kindled, the mixed shells and charcoal are to be laid in small heaps, of not more than the eighth of a parah each, at about a foot and a half apart, and when the fire has been communicated to them, the intermediate space must be filled up to a level, with more shells and charcoal, and when the fire has thoroughly extended to them also, another row is to be laid in heaps upon this mass, as was done in the first instance, and the subsequent operations are to be repeated in the same manner until the kiln is filled. The transverse arches exhibited in the Plate are to promote the requisite current of air, and the windward ones are invariably to be open, whilst those on the opposite side must be closed. The kilns are built of brick in clay and require renewal every three years. The shells will be sufficiently calcined in twelve hours, and twenty-four more are required to cool them, so as to admit of their being moved and the charcoal sifted from them. A moderate breeze both hastens the burning and renders it more complete.

Kilns are also made cylindrical, of the shape of an inverted cone and of two truncated cones placed base to base. The lime whose calcination is complete, is from time to time carefully drawn out through a passage in the bottom of these kilns, and fresh lime stone and fuel thrown in at top. Such kilns are sometimes constructed to burn lime for large engineering works, but the natives do not make use of them. In Plate IX, is the section of a kiln, used at one of the branches of the Godavery annicut. The arches of the four vents were constructed of brick in chunam, the interior of the kiln was of brick in clay, the exterior of rubble, and the plan a perfect square. The walls were strengthened by three timber frames. Six garces (of sixty parahs each) of slaked powder were obtained from it daily, and the kiln was drawn once a day.† Two and eight ninths cubic yards of

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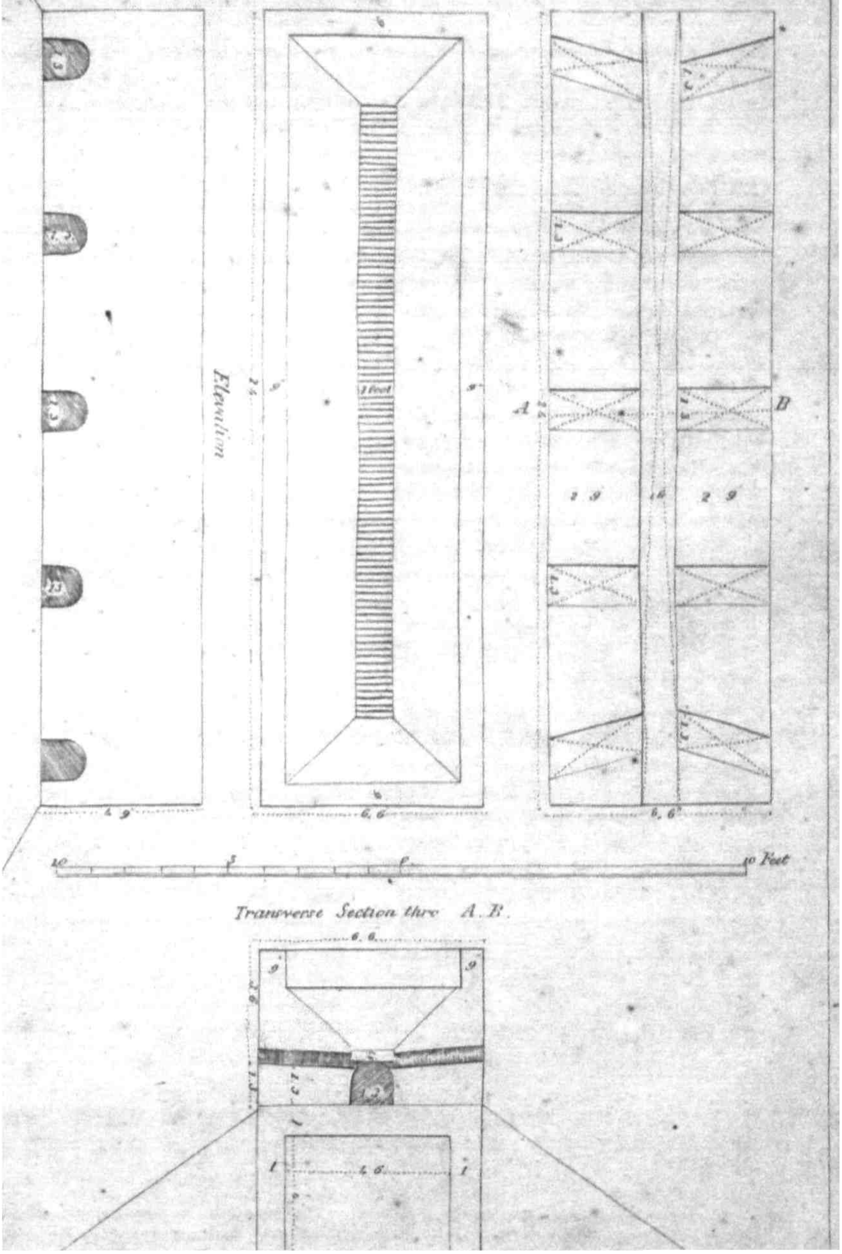
* The lime and charcoal are sometimes mixed in equal quantities.

1 parah = 40 meas. yields 60 parahs burnt shells, value about 35 Rs.
40 meas. = 1 parah chunam = $2\frac{1}{2}$ *cp.*
100 „ = 1 „ shells.
200 „ = 1 „ charcoal.

† The experienced lime burner will always know when the charge is sufficiently burnt; but those who have not had much practise should take out a piece of the stone

Plan Section and Elevation
of a
CHUNAM KILN



broken lime stone produced sixty parahs ($4\frac{23}{27}$ cubic yards) of slaked powder, and to burn that quantity, 3,000lbs. of wood and 300lbs. of charcoal or 4,000lbs. of wood alone were used.

The walls of the kilns ought to be thick, in order to retain as much heat as possible: the ordinary native plan is defective as there must be great loss of heat in such kilns. The proportion of fuel should be determined by trial, on the stone that is burning, as some kinds take more fuel than others. The length of time necessary for perfect calcination can only be ascertained by experience. It depends on the nature of the stone, the quality of the fuel, the draught of the kiln and the force of the wind.

On the Western Coast only shell-chunam is used and the shells are generally burned with wood, but sometimes, for finer work, with bratties. In burning with bratties (or dried cakes of cowdung) no kiln is used, but a rude heap constructed with alternate layers of bratties and shells, the quantity of each not being measured but guessed. The proportion is about $2\frac{1}{2}$ of bratties to 1 of shells by weight.

Slaking.—After the quick lime is removed from the kiln, it must be converted by slaking into the hydrate of lime. In slaking the lime, no more water should be used than is sufficient to convert it into a fine dry powder, and from a fourth to a third, the bulk of the lime is sufficient for the purpose, if carefully poured over it, the lime being at the time turned over with a hoe. The pure limes as before stated slake perfectly, but the impure limes will not do so unless they be first reduced to a powder by grinding. Five parahs of slaked powder were obtained at the Godavery annicut from three parahs of broken lime stone. The lime was of the hydraulic kind. At Madras, a parah of burned shells, after being slaked, will fill from one and a half to two parahs, but this is measuring the powder in the way it is measured for sale, that is, pouring it very lightly into the parah and not pressing it down at all. The lime should always be slaked in the vicinity of the work for which it is wanted, and not purchased ready slaked, as in the latter case, there is less security for its being fresh, and it may be mixed with ashes from the kiln. Quick lime will keep quick a considerable time, if packed in casks or well protected from access of air or damp, otherwise, (especially if it is of the hydraulic kind), it commences to absorb carbonic acid and is then rendered unfit for use.

Sand.—The sand, with which the lime is mixed, is generally obtained in this country from the beds of rivers and nullahs, also from pits and wells, and often requires no other preparation than being screened to get rid of the larger particles, but if it contain earthy or

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from the kiln, remove the outer coating, and slake the inside portion in water; if no effervescence ensues on the application of an acid having a stronger affinity for the base than the carbonic acid (nitric or sulphuric for instance), the calcination is complete.

Pure lime is incombustible, and, therefore, cannot be overburnt; but lime containing the impurities necessary to render it a weather lime, easily fuses and becomes covered with a kind of enamel; it slakes with great difficulty, sometimes it will not slake at all, but becomes reduced to a harsh powder altogether inert, and is called *dead* lime.

saline impurities, it will have to be washed before being used. The purity of sand may be judged of by placing a small quantity in a tumbler pouring clean water on it and stirring it up. If the sand is quite pure, it will scarcely soil the water, but if it contains much clay or vegetable matter, it will produce muddiness and discoloration of the water. The sand should not only be *clean, but sharp*, that is, the grains should be angular and not rounded by attrition. The use of sea sand should be avoided, if possible, as the salt which it contains, and from which it is difficult to free it, keeps the mortar in so damp a state as to prevent its setting well. After several washings in fresh water, sea sand might be used, but so much trouble is not likely to be taken in this country.

Mixing of the Mortar.—The lime in this country is generally slaked apart from the sand, but it is thought by some that it would make better mortar if slaked in contact with the sand. The plan would then be, to place the sand on the ground hollowed into a kind of basin, into which the lime is to be put and the proper quantity of water having been poured upon the lime, some of the sand is to be drawn over it by a hoe, and the heap left for a short time. The lime absorbs the water which, of course, disappears, great heat is evolved and the lumps of lime shortly swell and burst into a most impalpable powder. The heap is opened and moved about with a hoe to ascertain if the slaking is complete, or whether any solid lumps remain requiring more water; if not, the mass is moved about to produce incorporation of the sand and lime, and if the process has been properly conducted, the whole will be found in a very nearly dry state, as the lime will absorb most of the water out of the sand and any superfluous quantity will be driven off in steam owing to the great heat of the mixture. The next process should be the *screening*, and though it is a most essential one and involves very little additional expense or trouble, it is too often omitted. The screen should be about six feet long and three feet wide, having projecting sides like a box. It may be formed with slips of bamboo placed about a quarter of an inch apart, like the blinds which are hung up in the verandahs of houses. The screen is propped up, so as to stand at an angle of 45°, and the lime and sand are thrown against it with a mamooty; what passes through it is fit for mortar, while all that falls in front will be either stones that were contained in the sand or unslaked lime, or pieces of the latter, which, for want of sufficient calcination, remain in the state of lime stone, and therefore are incapable of slaking. Such refractory material is called *lime-core*, and by the native *kuppee*. A small quantity at a time is now to be taken from the heap of slaked lime and sand, put into a narrow trench, the sides of which are formed with stones or hard bricks, when it is made into a paste with water, (much water should not be used as the ingredients mix better in rather a dry state,) and beaten up by men or women, with stout sticks shod with iron, similar to those employed in separating rice from the husk. The mortar when thoroughly mixed is taken out of the trough and collected in conical heaps, where it remains till required. Or else, the lime and sand are ground in a circular trough, made of stone, by a stone wheel, turned by a pair of bullocks or a single bullock. The second method is found nearly if not quite as efficient as the first, and more econo-

mical, but it often does not receive a fair trial, as the natives are opposed to it as being an innovation on their ways. Two parts of sand are generally mixed with one of lime to form mortar, and, if there is to be a general rule on the subject, perhaps that will be found a good proportion. The *best* proportion in each case can be found alone by direct experiment, as some varieties of lime require more sand than others. Lime made from shells will bear three parts of sand, and some of the stone limes do not require more than one and a half parts of sand, but generally two parts will not be found too much. It is a great mistake to suppose that the strength of mortar is increased by increasing the proportion of lime, for such mortar, though it may be strong for the first few years, will not be found so durable as that containing a due proportion of sand. It is said that the more the mortar is beaten up, the less proportion of lime will suffice.

The best mortar is produced from recently burnt lime, and the sooner mortar is used after it is made, the better; for, as by exposure to the air, it becomes re-converted into carbonate of lime; it is desirable that the change should take place in the wall. In large works it is not possible to use the mortar quite fresh, for, it is necessary to have a large quantity ready, in order to prevent delays. The best way to preserve the mortar, is to put it into pits, the sides and bottom of which may be lined with bricks, and water should be poured on the top. It will sometimes have to be beaten up a second time before being used. Mortar made with hydraulic lime should be used with as little delay as possible.

The use of Jaggery.—When the mortar is brought on the work, it is again mixed with water, and Native bricklayers use a considerable quantity and so temper the mortar very thin. Stiff mortar is recommended by Vicat in his work on Cements, and is generally used by English builders, but the thin tempered, makes closer joints and is certainly easier to work with. The quality of the mortar does not appear to be affected by the quantity of water added to it, provided it is not in such excess as to cause a separation or subsidence of the sand from the lime. It has always been the custom in this country to mix a certain quantity of jaggery (coarse sugar) in the water used in tempering mortar, and experiments have shown that it exercises a beneficial influence, at all events, on the first hardening of the mortar. From a quarter to half a pound per gallon has been found to be a good proportion, the former for ordinary purposes, the latter for those parts of a work which demand particular attention. This would correspond to from 2½ to 5lbs. per parah of chunam. The Madras data formerly allowed 5lbs. of jaggery to 1,000 bricks, or to 7 parahs of chunam, for walls, and 1lb. per parah for arches, but the quantity has of late been very much reduced. It would be better to use none at all than to use it in the diminished quantity, which cannot possibly have any effect on the mortar. Jaggery will be found more useful with pure limes than with those having hydraulic properties.

To ascertain whether any advantage is derived from the use of *Jaggery* (coarse sugar) in mortar, so prevalent throughout India, small pillars were carefully built with mortar mixed up, some with sugared water, and some with lime water, and allowed to set for

nearly a month, when it was found that the tenacity of the former was about 74 pounds per superficial foot, while that of the latter was 81 pounds on the same area. Several experiments have before been made, and have since been repeated to the same effect; and there is no reason to believe that, in the end, any advantage is derived to the mortar by the use of saccharine matter. The mortar, from the *gluten* or *gum* the sugar contains appears more plastic with it, and the masons find it *works* better; but, in reality, it is an useless expense in the first instance, and is probably prejudicial to the final enduration of the cement; first, because there is a considerable quantity of gummy and earthy matter which may not combine so well; and secondly, because, as it is found that quick lime is with difficulty slaked in sugared water, when this is used many particles of lime may remain unslaked, or may be slaked *so late* as to disturb the crystallization after it has commenced; the use therefore of this ingredient was discontinued in this edifice, and the disuse of it generally has since been recommended for large and extensive works.

An account of St. Andrew's Bridge by Major Thomas Fiott de Havilland.

Cements.—Hydraulic lime stone is met with in many parts of India, and is very useful in the construction of irrigation and other works, the foundations of which have to be laid in damp situations. The property of hardening under water is due to the presence of argile or clay in the stone, which is then said to be an argillaceous lime stone. Hence artificial hydraulic lime can be manufactured by mixing lime and clay together. Excellent hydraulic cement has been lately made in Madras in the following manner. Ground slaked shell lime is intimately mixed with *fresh* blue clay, in the proportion of one part by measure of the former to one and a quarter of the latter. This mixture is to be made into balls of from two and a half to three inches in diameter, and these balls should be allowed time to dry sufficiently to prevent their sticking together, and no longer; they are then to be calcined until it is found that a piece of the cement will not effervesce on being dropped into a mixture of muriatic or other acid and water, but care must be taken to prevent the cement becoming vitrified, as that would be as bad as underburning. The cement is next to be ground to an impalpable powder and used as soon as possible. Some bricks joined together with this cement, and plastered with it on the outside, were immediately placed under water, and after remaining there twenty-four hours, it was found that the cement had set perfectly hard. The cement has been used in plastering the revetment of the Fort, under the water line, but not to any extent. The proportion of clay to lime is probably greater than necessary, for it is said that lime stone that contains but six per cent. of clay is perceptibly hydraulic; when it contains fifteen to twenty per cent. it is very good, and with from twenty-five to thirty per cent. the mortar sets almost instantly.

Cement is stated to have been made in Bombay, with a mixture of lime and black cotton soil, and in the following manner. The soil is to be mixed with water and strained through a fine sieve, in order to separate all vegetable fibre and coarse particles. The resulting fine mud is to be dried in the sun, and broken up into small pieces,

and baked, until it will neither soil nor form a paste with water (much burning will spoil it); it is then to be ground into a fine powder, and mixed with quick lime in the proportions of from one to two parts of quick lime to one of the powdered baked earth. The second proportion is the best for general purposes, and when the chunam stone is impure, a less quantity of the baked soil must be used. This cement must, however, be inferior to the one before described; indeed, experiments seem to show that if the clay is baked alone, powdered and added to the lime, it will merely act as sand without altering the character of the mortar, and that no benefit will result from the admixture of clay, unless it is baked in combination with the lime, whence it is to be inferred, that the fire acting at the same time upon the two substances, produces some change in their internal arrangements, by which the character of the compound is affected, but the real nature of the change has not been satisfactorily explained.

Cement Chunam.—This cement is made with a mixture of one part of pounded brick, one of lime and one of sand, or with two parts of pounded brick to one of lime; other proportions are also in use. If made with fresh well burned bricks, it possesses hydraulic properties, but its durability is very questionable; when applied as a plaster to walls it has, in some instances, after a time, crumbled to powder. Taking into consideration what has been said in the last paragraph, this cement should be used very sparingly. In Bengal a mixture of two parts of brick powder and one of lime is often used for hydraulic works. The two ingredients are ground dry under a grinding stone, and then slaked with just sufficient water to convert them into a paste. The quality of the cement is said to depend greatly on the lime being slaked whilst in contact with the brick powder. So little do the Maistries appear to be aware of the object of using pounded brick, that if questioned on the subject, they will say it is added to obtain a red color. A mixture of brick powder and lime with oil is sometimes employed as a lining to cisterns.

Magnesia cement.—Magnesia is found in the Salem and Trichinopoly districts, and no doubt in other parts of India, and forms with sand or pounded iron stone an excellent cement for hydraulic works. The stone should be broken into pieces about three inches thick and burned for about twenty-four hours, afterwards pounded in a mortar, passed through a sieve and mixed with one and a half or two parts of sand. A mixture of equal parts of magnesia, iron stone and sand, also of one part of magnesia with two of iron stone and three of sand, have been found to set readily under water and become exceedingly hard. The laterite or iron stone should be reduced to a fine powder, but not calcined; and it is desirable that the cement should be allowed half an hour to dry before being immersed in water.

Portland cement.—Portland cement is an article now so largely imported, and so generally used in the engineering works of the present day, that it is astonishing that its manufacture is not more vigorously undertaken in Madras. The merchants whose kilns at the basin line the east bank of the canal, and who traffic so largely in shells and chunam, should have ere this experienced a fall in the sale of chunam, as cement

Plastering.—Under this head may be included everything that relates to the spreading evenly and smoothly on the surface of walls, externally as well as internally, and on ceilings, a composition of mortar or cement; and also all the ornamental and decorative parts of buildings. This is a part of the plasterer's business, which requires the greatest care, both with respect to the method of working and the quality of the material used.

The following is the method of plastering walls at Madras :—

For one coat, the plaster is composed of one part of lime and one and a half of river sand, thoroughly mixed and well-beaten up with water. Before applying the plaster, the wall should be trimmed with a trowel, and swept perfectly clean, and then sprinkled with water. The wall being ready, the plaster is mixed up with jaggery water and brought to the required consistency. It is then laid on with a trowel, about half an inch thick, and levelled with a flat wooden rule, being afterwards smoothed with a wooden rubber, till it acquires an even surface. During the process of rubbing, the plaster is occasionally sprinkled with a little pure lime mixed with water, to give it a hard and even surface.

For two coats, the first coat is applied as already described, with the exception that the surface is left rough, and no pure lime is applied during the process of rubbing. A day or two after the first coat is put on, and while it is moist, the second coat is applied. The plaster used for the second coat consists of three parts of lime and one of *white* sand. These are mixed, as before, and afterwards ground by women on a flat stone, with a small stone roller,* till they are reduced to a fine paste. The plaster thus prepared is laid on a wooden rubber and applied with care, over the first coat, about the eighth of an inch thick. It is then rubbed down perfectly smooth, with a small trowel, and afterwards polished with a crystal or smooth stone rubber, and as soon as it has acquired a polish, a little very fine *ballapum*† (soap stone) powder is sprinkled on it to increase the whiteness and polish of the plaster, and the polishing continued. The second coat ought to be applied and finished in one day, for it usually hardens too much during the night to be polished the following day, unless in damp weather. The practise is to continue polishing the plaster until it is quite dry, and a number of bricklayers are employed in order that it may be well polished the first day. Moisture continues to exude from the plaster for some days after it is completed; this ought to be carefully wiped off with a fine cloth and the wall kept perfectly dry till the moisture ceases.

1st.—Rough Chunam.

2nd.—Kurpoo Vella—see Notes.

3rd.—Mail vella, white and lime, ground.

4th.—Koippoo.

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* Mortar for cut stone work is ground on a stone in the same way.

† The ballapum powder is tied up in a cloth, and dusted over the wall, as pumice is applied to paper, by which means, the finest parts only are used.

Ballapum is the Canarese, and *mavoo kulloo*, the Tamil name of pot stone or soap stone (steatite), which is a softish stone of a greyish blue color, found in many tracts of lower India; particularly in Mysore. It is easily worked, and is used by the Natives for

For three coats, the first is laid on as already described, but it is left a fortnight or three weeks to dry before the second coat is applied. The plaster for the second coat (kurpoo vella) consists of one part of lime and one of fine river sand, freed from the coarser particles and from clay by sifting. It is well mixed and beaten up in a clean trough and applied over the first coat, about a quarter of an inch in thickness, the first coat being previously moistened with a little water. It is next rubbed down in the same manner as the first coat, but acquires a much smoother surface, the plaster being of a finer quality. A day or two afterwards, before it has had time to dry, the third coat (mail vella) is applied. It consists of four parts of lime and one of fine *white* sand. These after being well mixed and reduced by grinding to a very fine paste, quite free from grittiness, are put into a large earthen jar, of the size nearly of half a hogshead, and mixed with the whites of eggs and tyre, or milk curds, in the proportion of 12 eggs and 1½ measures of tyre to every parah of plaster.* These are all mixed and rubbed between the hands, till the ingredients are thoroughly incorporated, and the composition reduced to a uniform consistent paste, a little thicker than cream and perfectly free from grittiness. The plaster is now fit for use and is put on with a wooden rubber, about a tenth of an inch thick, and gently rubbed till it becomes perfectly smooth. Immediately after this, another coat of still finer (koippoo) plaster is applied, consisting of pure lime ground to a very fine paste, and afterwards mixed with water in a clean tub, till it is of the consistency of cream. This is put on about a sixteenth of an inch thick with a brush and rubbed gently with a small trowel till it acquires a slight degree of hardness. It is then rubbed with the crystal or stone rubber till a beautiful polish is produced, not forgetting to sprinkle the wall with fine ballapum powder during the process of polishing. If the plaster is not entirely dry on the second morning, the operation of polishing ought to be continued until it is quite dry. The moisture, as above directed, must be carefully wiped off and the wall kept quite dry till all appearance of moisture ceases. The quality of the chunam depends chiefly on the plaster for the upper coat being reduced to a very fine paste, perfectly free from grittiness, and on its being, after it is applied to the wall, rubbed constantly with great care, till it is quite dry and has acquired a very fine polish. The wall ought then to be frequently wiped with a fine clean cloth to remove the moisture, and it may be occasionally dusted with ballapum powder. The stone used in polishing is a crystal or white pebble or piece of soap stone, about three inches long and one and a quarter broad, with a perfectly smooth face. In the upper coat, very white sand only is employed, as common sand destroys the brilliancy of the plaster. When white sand is not procurable, white crystal, or pebbles reduced to a fine powder, may be substituted. The thickness of plaster is from three quarters of an inch to an inch, and is made so

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making small pots, and dishes, and also pencils for school boys to write upon books with; which books are formed of cloth blackened, and stiffened with gum. There is a variety of this stone which is more hard, and is called in Mysore *sila kulloo*, from the circumstance that it is generally used for making images.

* Sometimes half a pound of ghee is mixed with the above quantities of white of egg and tyre. Other proportions of the ingredients are in use.

while to work deep. For arch work, laterite should not be trusted in spans over 30 feet, except where the stone can be picked or is from a first-rate quarry. Laterite is said to harden on exposure to the air after being cut, which supposition would warrant its being quarried several seasons before use, but it is doubtful whether this hardening is more than superficial. Every laterite building should be carefully pointed with chunam on first completion, and the pointing renewed as occasion requires, as it is a material very susceptible of destruction by plants growing from the seeds which may happen to lodge on the face of a wall. Half the amount of chunam used in brick-laying will suffice to lay an equal amount of laterite-masonry built with stones of the usual size.

Granite.—This is one of the most common rocks in lower India, and is met with both in strata and unstratified. True granite is a compound of *quartz, felspar* and *mica*, not chemically united with each other, but so closely aggregated, that when the grain is fine, it is difficult to distinguish one from the other; but, if coarse, the three materials appear almost distinct. In this stone the quartz may be said to be imperishable. The felspar is durable, but still gradually decomposes by exposure, and the mica which is a glittering substance, always soft, and of no importance as to the value of the stone, soon gives way and disappears. Instead of the mica, another substance, called *hornblende*, is found in some granites which are then called *sienite*. Sienite is harder and more difficult to work than real granite and is one of the best stones for building purposes.

Quarrying stone.—The stones used for facing the inner slopes of tank banks are usually boulders, from one to two feet in length, which are picked up on the sides of hills or dug out from a short distance below the surface of the ground. These stones are also used set in mortar, in foundations, and for building road tunnels, &c., and when broken up, as road metal. The stones used in building choultries and facing the lower part of pagodas have always been detached from their natural bed by means of steel wedges, with or without the assistance of fire. In the Bellary district, where granite is extensively used, not only for the above purposes, but also for building houses, the method of quarrying is as follows:

The first point is to select as clear and extensive a surface of rock as possible, on which heavy logs of wood are laid, and kept in a state of ignition for about two hours. The rock is then struck with a crowbar, to ascertain from the sound if a crack has been made, and when this is found to be the case, a large heap of light fuel, such as the thorny branches of the Mimosa, which is very abundant in the plains of Bellary, is burned for about the same period, or less, according to circumstances, when the upper lamina, before partially detached, may be expected to separate decidedly from the rock; its disjunction being marked by a sound, which guides the workmen in removing the ashes. They then insert wedges into the crevice, driving them as far as possible, and throwing heavy weights on the surface, break the stone into pieces of the required size, the small stone and splinter, which come off at the same time being very useful as rubble. The time occupied in this operation varies according to the character of the rock, and the thickness of stone required: it is also greatly influenced by atmospheric

temperature, being much less in hot than in cold or wet weather. The weights used for breaking the stone or boulders of trap or greenstone, obtained from the dykes of that rock which traverse the country: these are extremely heavy, and are thrown down with the utmost force. When flags for flooring, or other purposes are required, the rock is first heated and partially separated: a line of holes a few inches apart is then chiselled according to the intended dimensions, and the flags are separated by steel wedges being inserted in these holes, and forcibly struck by a hammer, in the same manner as the rock is cut in every part of the country, where the aid of fire is not employed. In quarrying flags of any length, uniform thickness cannot be depended upon, one end of a stone may be 3 inches, and the other from 6 to 8 inches in depth. Much depends on the character of the rock, and on the carefulness and skill of the workmen. Thin laminœ are occasionally separated, measuring 10 or 12 feet square, but as the brittleness of the stone is greatly increased by burning, such slabs are of little or no use.

The size of building stones varies according to the nature of the work in which they are to be employed. For facings to tanks or wells, the stones ordinarily average 18 inches square, and 12 in thickness. For the walls of large buildings 2 feet thick, the best size of stone is about 10 or 12 inches by 5 or 6 inches thick; dimensions somewhat less are applicable to the ordinary breadth of wall, which is 18 inches, and for very common works, a third, and inferior size is made use of.

The prices of these stones at Bellary are as follows, and include the carriage from the quarry to almost every part of the station.

			RS.	A.	P.
Tank stones		per 1,000	20	0	0
Building stones	First sort,	4 per cubic foot...	4	0	0
	Second sort,	6 do ...	2	8	0
	Third sort,	9 or 10 do ...	2	0	0

Flooring flags are usually 18 inches square, and cost 5 rupees per 100, which includes only the expense of burning and carriage; the cutting forming a separate charge of nearly equal amount.

In the neighbourhood of Madras, fire is not employed for separating the stone; the method of quarrying is as follows:

Having selected a part of the rock, where there appears to be a sufficient depth of good stone, the upper crust which generally consists of stone of an inferior quality, is removed by blasting to the requisite depth, about 1 or 2 feet, and the solid mass below thus laid bare. Holes of about 4 inches square and from 3 to 4 inches deep (according to the thickness of the stone required) are then cut at a distance of from 4 to 6 inches in the line of the intended fracture. Iron wedges are inserted, and being repeatedly struck with a large hammer formed of hard stone, slung in a pliable wooden frame, a large mass is thus detached. This mass, (except in cases where very large stones are required) is again broken up into smaller ones by inserting wedges along the intended lines of fracture as before, with this difference that the wedges are much smaller and placed much closer

together. The stone then receives two dressings with heavy chisels, by which the greater inequalities are reduced and is then ready for transport to the work. As the fracture is frequently very irregular, in order to avoid all risk of the stone being short of the requisite dimensions, the quarrymen are constantly in the habit of making it much too large, whereby the labor of reducing it to the proper form is materially increased. By driving the smaller wedges rather deeper and with more care, a more regular fracture would be produced, and indeed it would be well worth while to run the risk of spoiling many stones, rather than to make those which are sent to the work, so much in excess of the requisite size. The quarry at the Seven Pagodas, situated on the coast about 35 miles to the South of Madras, yields a stone of a light color which is split very readily by wedges. Blocks of very great length have been obtained from this quarry.

Blasting Rock.—In constructing roads among hills, and in digging channels, rock will often be met with which it will be necessary to remove by blasting; but recourse should not be had to gunpowder, when there are other means of effecting the purpose. Rock may often be removed by lighting large fires upon it, and extinguishing them with cold water, which causes it to crack. When granite is of a grey color, with white streaks resembling the grain in a plank, it will generally be easily split in this manner. Large boulders are often most easily got rid by digging pits below and rolling them in and covering them.

The implements used in blasting are of a simple character and consist of the *jumper*, with which the holes are made; the *scraper* or *spoon* for clearing the hole of the chips produced, the *needle*, which is driven into the charge and remains while the hole is filled up with stones, &c., so that, when ultimately withdrawn, a channel is preserved communicating directly with the powder. While the needle, which is a long thin copper or iron rod, remains in its place, the space around it is filled up by means of the *tamping bar* with stones, &c. The operations which constitute the entire process of blasting are, boring the holes, loading and firing. The *jumper* is an iron bar of variable length, according to the depth required for the blast. Its two ends are tipped with steel, formed like knife edges, their length across depending on the diameter of the hole for which they are to be used. In using the jumper, one man sits down on the rock in a convenient posture, and holding the lower part near the bit, he guides it that it may strike fair in the hole. Another man stands upright, and raising the jumper, perhaps a foot above the surface of the rock, he drives it forcibly home. At intervals, a little water is poured in, by which the rock is to a certain extent softened, and the dust formed by the jumper is made of a pasty consistency, and thus more easily removed. For the purpose of doing this, a metal spoon is used, consisting of an iron rod having one of its extremities beaten out and curved so as to form a grove, like half a hollow cylinder. The under part of this is closed by a semi-circular disc on which the mud filling the groove rests. After the hole has been sunk to the proper depth, and the charge deposited, it must be tamped or filled in again, so that a due resistance may be offered to the explosive force of the powder, and

that this force may be directed through the line of least resistance, which is measured from the centre of the charge to the nearest surface of the rock. The best material for tamping is small fragments of the rock in which the blasts are being prepared, but it is never free from danger in giving fire and causing accidents. Ant hill earth has been found to be the next best, then clay, then wet sand, while dry sand is the worst, that is, offers least resistance to the force of the powder.

The tamping bar is a heavy brass rod, of a diameter a little less than that of the hole in which it is to be used, and slightly tapering at the extremities. At each end, an open groove is formed along the side, to admit of the bar being used with facility, while the needle, to be described immediately, is placed in the hole. Brass is selected for tamping bars, to avoid the risk of accidents from the charge being ignited by sparks, which would be struck were iron or steel to be employed. In using the bar, the tamping material is put into the hole, in small quantities, sufficient to fill from an inch to an inch and a half at a time, and each is well and firmly rammed home by successive blows. The time required varies with the material used, and the quality of the tamping depends much on the dexterity of those employed. Through the tamping, it is necessary that a communication with the charge for the purpose of priming should be made. This is done by means of the priming needle, which is a thin metal rod having a loop handle at one extremity, and pointed at the other. Copper is a bad material for priming needles on account of its softness; those of iron about 1-16th of an inch in diameter answer better, and to guard against accident by sparks being struck by them, they may be tipped with brass. In using the needle, it is necessary to grease it well before the tamping is commenced, and to turn it frequently during the process, since the friction ultimately becomes so great as to cause nearly half the time required for tamping to be consumed in withdrawing the priming needle.

The charges of powder should be as the cubes of the lines of least resistance. Thus, if 4 ounces of powder would have a given effect upon a solid piece of rock of 2 feet thick to the surface, it ought to require 13½ ounces to produce the same effect upon a piece of similar rock 3 feet thick; for, 8 (the cube of 2) is to 27 (the cube of 3) as 4 is to 13½. On this datum, the following table has been formed:—

Line of least resistance.		Charges of powder.		Line of least resistance.		Charges of powder.	
Feet.	*Inches.*	*lbs.*	*oz.*	*Feet.*	*Inches.*	*lbs.*	*oz.*
1	0	0	0½	4	0	2	0
1	6	0	1¾	4	6	2	13½
2	0	0	4	5	0	3	14½
2	6	0	7¾	6	0	6	12
3	0	0	13½	7	0	10	11½
3	6	1	5½	8	0	16	0

The effect produced will depend on the nature of the rock, the quality of the powder, and on the tamping. The results of the first two

or three blasts should be carefully noted and the charges can be afterwards regulated according to the rule that has been given.

The following table will give the means of calculating the space occupied by any given quantity of powder in round holes of different sizes from 1 to 3 inches:—

Diameter of the Hole.	Powder in one inch of Hole.		Powder in one foot of Hole.		Depth of Hole to contain one lb. of Powder.
Inches.	*lbs.*	*oz.*	*lbs.*	*oz.*	*Inches.*
1	0	0·419	0	5·028	38·197
1½	0	0·942	0	11·304	16·976
2	0	1·676	1	4·112	9·549
2½	0	2·618	1	15·416	6·112
3	0	3·770	2	13·240	4·244

The space occupied by the priming needle is filled with fine powder (which is sometimes confined in a straw or fine reed) and is fired by means of a slow match, made of paper or linen soaked in a strong solution of nitre or gunpowder, and this must be so arranged as to give the person firing it time to retreat before the powder explodes.

Holes 2 feet deep and 1½ inches in diameter may easily be bored in a day through sienite by men accustomed to the work. Many of the tank diggers employed in road work understand the way of boring the holes and applying the charges, and will undertake the work either at so much the cubic yard of rock removed, or so much per foot of hole bored; when they are working under superintendence, the latter arrangement had better be made with them.

Section 4.—Paints, Varnishes, &c.

The material chiefly employed in painting is white lead. It is a carbonate of lead produced by the action of the vapour of vinegar on sheet lead; and when ground up with linseed oil, forms the common white lead paint of commerce. It is improved by being kept several years. To produce the different tints, various colors are added to the white lead base, in quantity according to the intensity of the tint desired, amounting sometimes to an exclusion of white lead in the upper or finishing coats.

The following are the colors generally used. White, black, lead color, red, and green. White is produced by mixing white lead and linseed oil together. White paint may be procured ready mixed, requiring merely to be diluted with more oil before being used, or the white lead may be procured separately and afterwards ground up with oil. Pure white lead is difficult to procure in the Madras market. The material sold under that name being adulterated to a great extent with sulphate of barytes, or even with powdered chalk. It is of great importance that white lead, which is used as a primer to the other colors, should be pure, or the paint will not be durable. Black is produced by lamp black, which is soot collected from the burning of resinous sub-

stances. Black paint is imported ready mixed, and it is also prepared in the country. Lead color is produced by mixing a small quantity of lamp black with white lead. Red paint is made with red ochre, which, being extremely cheap, the sellers have no object in adulterating it. This paint is sometimes used with wood oil, and without any mixture of white lead, but it is not durable. The green paint generally used is what is called *keg paint*, which is imported mixed with oil, and is often composed of indigo and yellow ochre or chalk and copperas. It answers tolerably in the interior of houses, but if at all exposed, it quickly falls off in powder. The best pigment of this color is verdigris, which is produced by the action of vegetable acids on copper. It is sold in lumps which must be ground to a fine powder. It is much more expensive than the other paint, but it is much more durable; indeed, it is useless to apply the common green paint in places where it will be exposed to the sun.*

White zinc or oxide of zinc is in use as a substitute for white lead; it is stated in Hunt's Hand-book that this zinc which, "although of a a beautifully white color, is unfortunately to a certain degree, transparent; and it is stated by the painters, that it does not possess, the covering properties or the body, of the carbonate of lead. Another difficulty attending the use of zinc paint, arises from the circumstance that it remains on the wood a long time before becoming sufficiently hardened to admit of a second coat being laid on; whilst as most of the compounds sold under the name of *patent dryers* contain lead, the introduction of this substance gives it the property of becoming black when exposed to sulphuretted hydrogen, and thus entirely destroys one of its most valuable characteristics. This arises from the fact, that the oxide of zinc will not combine with oil to form a plaster, in the way in which the oxide of lead does. It is much to be wished that the resources of modern chemistry may be at length found equal to the removal of this disadvantage; as from the baneful influence exerted by white lead, both on the persons who are employed in its manufacture, and on the painters by whom it is applied, it is greatly to be desired that some good and equally cheap substitute for this substance may be discovered."

To hasten the drying of paints *dryers* are used, but not generally in this country. Those most in use are sugar of lead, litharge and white copperas. Sugar of lead is the best, though somewhat more expensive than the others. A very good drying oil is made by boiling one gallon of linseed oil with a quarter of a pound of litharge, or red lead reduced to a fine powder. It must be kept slightly boiling for about two hours, or until it ceases to throw up any scum; when cold, the clear oil must be poured off and kept for use.

Grinding Colors.—All substances employed for painting in oil require to be ground up with a small portion of the oil previous to mixing them with the whole quantity required for use; for this purpose they must first be pounded and passed through a tolerably fine sieve, then mixed with a portion of linseed oil, just sufficient to saturate them; a quantity about the size of an egg, is to be taken on

* The paints used in public works might be limited to two kinds—viz., green paint, (verdigris): white paint, (white lead).

the point of a knife and placed on the grinding stone, which is a slab of porphyry or granite, about two feet square; the chief requisite is that it be hard and close grained. The *muller* is then placed upon it and moved round about or to and fro in all directions, bearing a little weight on it at the same time. The muller is a hard and conical formed stone, the diameter of the base or rubbing surface of which should be about one-sixth of that of the grindstone, and the cone high enough to get a sufficient hold of it with the hands. The face of both grindstone and muller should be perfectly smooth. The rubbing should be continued until the paint is ground perfectly fine, having the consistence and smoothness of butter. The color must be occasionally trimmed from the edges of the stone and muller with a knife, and put under the muller in the middle of the stone. When sufficiently ground, it is removed from the stone and a fresh quantity taken. It is not well to have too much color on the stone at one time; it makes it more laborious and will take a longer time to grind the same quantity equally well.

Mixing colors for Painting.—Before the colors which have been ground can be applied to the work, they must be rendered fluid by the addition of linseed oil. When a tinted color is required to be mixed up, a small quantity of the proper tint should first be prepared, which will serve as a guide to mix the whole quantity by. With the ground white lead there should first be well mixed a portion of oil, and then the tinting color should be added as ascertained by the pattern previously prepared. When these are thoroughly mixed and matched to the proper tint, the remaining portion of the oil is to be added; this is better than putting in all the oil at once. It should then be strained through a piece of fine canvass, or a fine sieve, and should be about the consistence of cream or just so as to work easily. If it is too thick, the work will have an uneven cloudy appearance, and it will be hard to spread; while, if it be too thin, it will be likely to run or will require a greater number of coats to cover the ground and render the work solid. The straining ought not to be neglected when the appearance of the work is studied.

Painting new woodwork.—The first operation of the painter is to cover (or as it is called *kill*) the knots, to prevent the turpentine which they contain from oozing out, which would create an unsightly appearance not easily repaired after the work is finished. Red lead finely ground in water and mixed with some double size (glue reduced to a certain consistency by water) is applied warm to the knots, which, when dry, should receive a second covering if necessary. This process will generally leave a film which must be rubbed down. Teak and some other woods used in India will not require to be treated in this manner. The work must be well dusted, and the first color, or priming, as it is called, laid on, which, when dry, must be lightly rubbed off with pumice stone and dusted off. The heads of nails and brads, having been punched in, will present indentations which must be stopped with putty (made with pounded whiting and linseed oil) and the second color laid on, and, when dry and sufficiently hard, skimmed over with glass paper, dusted off, and the third color applied. If the work is to have four coats, a day or two must be allowed for the paint

to harden, when it must be gently rubbed down with glass paper as before, and the fourth or finishing coat laid on. No hair marks from the brush should be left on the work, or puddles in the corners of panels, angles of mouldings, &c. Work executed in this manner has a solid and uniform appearance, and there is no comparison between this mode and the slovenly way frequently practised.

Painting old work.—If the work is very dirty, it should be scoured with soap and water, or if foul with smoke and grease, it should be lime washed to absorb the grease, or the paint will not dry. When the wash is dry, it must be well rubbed down with pumice stone and dusted off. If there are any parts of the paint chipped off or blistered, which require scraping or rubbing down, this must be attended to, and the parts brought forward by touching them with color, three or four times over, before the painting of the surface is commenced. When these patches are hard enough, they may be slightly rubbed down and the color laid on; when dry, stopped with putty, rubbed down with glass paper, and finished as in new work. Sometimes the work is so much disfigured by blisters, that it is necessary to burn off the old paint, in which case, the surface must be well scraped and pumiced down before the first coat is laid on.

All work should be perfectly dry before being painted, for, if dampness or moisture in woods be stopped in with paint, it will tend to destroy them and in stuccoes it will spoil the paint.

Wood oil.—Instead of being painted, doors, windows and roof timbers are often varnished with wood oil, which is a liquid resin, obtained from the wood of several trees by the action of fire, in nearly the same way that tar is in Europe. Wood oil of a superior kind is brought to India for sale from the Ava dominions. It is a cheap and durable material, and improves the appearance of wood work. It is prepared for use by being boiled with a little white dammer (rosin) which gives it a polish, and causes it to dry quicker. The dammer had better be omitted when the wood is likely to be rubbed or exposed much to the air.

Palmyras are usually tarred, in order to be better preserved against the attacks of white ants. The tar should be boiled before being applied.

The following compositions for protecting plaster exposed to the weather are stated to have succeeded, but they have probably not been tried in India. For important work, three parts of linseed oil boiled with one-sixth of its weight of litharge and one part of wax. In common works, one part of linseed oil, one-tenth of its weight of litharge, and two or three parts of resin. The surfaces must be thoroughly dry before applying the compositions, which should be laid on hot with a brush.

Protection of Timber from White Ants.—The following Recipes are given as they may be found useful for preserving Timber from the Ravages of White Ants. The Madras Recipe has been successfully used as a coating under rattan mats and carpets, but is always used

with caution for these purposes, and it is not generally adopted on account of its being poisonous.

Captain Fraser's Process.—In 1856, the Magazine flooring and powder-racks in Fort William, Calcutta, had to be renewed in consequence of the injuries caused by white ants.

Captain Fraser, R.E., removed the whole of the old floor, stripped the plaster from the walls, for a height of 4 feet, and dug out the earth to a depth of 1 foot.

The excavation was filled up with concrete; masonry pillars were built for the support of the joists, which were painted and overlaid with 3 inch planks, and the walls were re-plastered.

The concrete, the mortar in the masonry pillars, all contained a proportion of the yellow arsenic, proportions used being as follows:—

100 cubic feet	concrete............	4lbs. Arsenic.
100 ,,	masonry............	½lb ,,
100 Sq. feet	plastering............	½lb ,,

Paint a small quantity.

The plan was perfectly successful. Captain Fraser writes—

" In 1856 not only the building, but the whole immediate neighbourhood was swarming with white ants. " In 1859, or three years afterwards, the Town-Major reported that " the flooring and powder racks in the king's Magazine have been carefully examined, and no traces of white ants have been found either inside or outside the building."

On the 16th March 1874, the Executive Engineer, Fort William, in reply to an inquiry on the subject reported as follows:—

" Since 1859, no repairs have been executed to the floor racks of the kings's Magazine; no traces of white ants are to be found, and the floors and racks are in fair condition."

So the process appears to have met with complete success.

Bombay D. P. W. Recipe.—Bombay Chief Engineer's recipe 1858. —A mixture of sulphate of copper, or arsenic, with the lime in immediate contact with timber, offers, perhaps, the most ready method of preserving it from insects; corrosive sublimate combines with lime, and forms inert substance (' yellow wash' of medicine).

Madras Recipe—

	lbs.	oz.
Arsenic..	2	4
Aloes..	2	4
Chunam soap, (common country)..............	2	13
Dhobies' earth..	2	8

Pound the arsenic and aloes, scrape the soap, mix with the earth, and boil in a large chatty half full of water, until it bubbles; let it cool, and when cold, fill up with cold water; the mixture should be boiled for an hour. It is applied as a wash.

Take (1) white arsenic, (2) country soap, (3) country aloes and (4) dhobies' earth, of each 1 viss or 3 lbs. weight, dissolve the dhobies' earth in 30 Madras measures of water by mixing it with the hand in the

water, and strain the mixture: reduce the arsenic and aloes separately into powder, cut the country soap into thin slices, then add the arsenic, aloes and soap to the water and boil the whole over a brisk fire in an ordinary earthen vessel. As aloes is one of the ingredients of the mixture, a very unpleasant smell will be emitted during the process of boiling, and it will readily be perceived that the addition of the arsenic renders it a poisonous compound. It is therefore necessary that the man who prepares the same should not even inhale the fumes emitted during the act of boiling. He need not stand by while it is being boiled, but retire to some distance, and approach to stir up the solution, perhaps only once or twice during the process, until it is all over, when it will have attained the consistency of syrup. It should then be removed from the fire and allowed to cool. The following day it may be applied with an ordinary brush to the floor, and if the application be repeated twice again, at intervals of 3 or 4 days, it will be found that the ravages of the white ants have been completely subdued. The only objection to the use of this antidote, is, that it is of a dark brown color, which color it will impart to any object to which it may be applied; but this is a trifle compared to the good done. Double the quantities of each of the ingredients named above sufficed for the floor of a room 40 × 26 feet.

Filling cracks in Roofs.—First, loosely caulk the cracks with hemp, then pour in Portland cement mixed with water to the consistency of cream.

The best recipe for filling up cracks in a pucka roof is linseed oil 2 seers, resin 2 seers, pumice stone or jhama 1 seer.

The following is a good method for filling up cracks in pucka terraced roofs. Take of linseed oil 2 seers, resin 2 seers, pumice stone (jhama) 1 seer—boil the oil, pound resin fine and then mix. Next pound the jhama also very fine and mix. The cracks should not be disturbed or dug out, but the mixture poured in and smoothed over with a trowel.

Bangalore D. P. W. Recipe.—The following specification is given in the estimate for the Museum at Bangalore.

"A thin layer of the following composition to be laid over all walls at basement level, and again 1 foot below their tops to keep off white ants from the floors and roofs.

8 bottles of coal tar.
1 bottle of linseed oil.
3 drams of kerosene.
2 lbs of asphalte.

It is not known whether this preparation has been practically tried.

Burmah D. P. W. Recipe.—Mr. Bennett, Executive Engineer reports that, "in British Burmah, Port Blair, where the majority of buildings were wooden structures, the whole of the timber is coated with earth-oil, which is laid on warm before the timber is put into the building, yearly coatings being also laid on prior to the rains. The effect of this is very surprising. The cost is 8 to 12 Ans. per square of 100 feet."

CHAPTER III.

FOUNDATIONS.

The first thing to be done before commencing any building, is to ascertain the nature of the soil on which it is to be raised, for on it will depend the measures to be adopted for procuring for the foundation an unyielding bed, without which the structure will possess neither stability nor durability.

In the case of houses, a mere examination of the surface of the ground will generally be sufficient, and the experience acquired in building houses in the neighbourhood, will show what soil is likely to be met with beneath the surface; or to set all doubts at rest, a hole two or three feet deep might be dug on the intended site. But when works are to be built in the beds of rivers and similar situations, the nature of the soil is best ascertained by probing the ground with an iron rod having hollows scooped out of the side, and a sharp conical steel point. The soil in the hollows will give some indication, and the depth to which the probe is driven will give more; but it must not be assumed, from the probe accidentally striking against a small stone, that rock will be found to build upon. In sandy soils any deep excavation near the foundation, should be avoided or carefully filled up, as the weight of the building will have a great tendency to force the sand from underneath, and drive it into the hollow.

Foundations on rock.—Before building on rock, the thickness of the stratum should be ascertained; should there be any doubts respecting it, and any portions that present indications of having been injured by the weather should be carefully removed. It is not necessary that the surface should be brought to a perfect level, for projecting points are often desirable, and, if the structure is to be raised with bricks, they can easily be built round. If the rock present a smooth surface considerably inclined to the horizon, it must be broken into steps which would cost less than bringing the whole surface to one uniform level; but if the inclination be moderate, say under 30° the cutting into steps will not be necessary, as the vertical pressure will not cause the masonry to slide, more especially if the surface be uneven.

Foundations on firm soils.—When the soil is hard clay, gravel, or sand, a trench must be cut through the upper vegetable mould into the natural firm soil of the country, and a depth of from 2½ to 5 feet will generally be sufficient. The object of carrying the foundation of a building below the surface of the ground, is to guard against the bottom of the masonry being exposed and undermined; and, where the

soil is easily compressible, or loose, to obtain a firm footing. The trench should be perfectly level at the bottom, and need not be much wider than the intended width of the bottom course of masonry. If a foundation has to be formed in the slope of a hill, that foundation should not follow the slope of such hill, but should be cut in level steps, like a staircase, except that the level portions may extend considerable distances. Sand is almost proverbially a bad foundation to build upon; but it is only so when not confined, as in an open beach, where it is liable to be washed away or even drifted by the winds, so that the wall may become undermined. But when sand is met with in the bottom of a foundation trench, in a tolerably dry state, and is to be covered on its upper surface with the intended erection, it may, in general, be trusted to as safely as soil of a more compact and fixed kind.

In compressible soils, such as some kinds of clay, sand may be used to form a bed for the foundation. For this purpose a trench is excavated from 4 to 6 feet in depth, and filled with 2 or 3 feet of sand, which should be wetted and spread in layers of about six inches, and each layer firmly rammed before the next is laid. The sand transmits the pressure laid upon it not only over the bottom of the trench, but over the sides, so that, unless lateral yielding takes place, a very great resistance is offered to the pressure and great stability is secured. In very soft ground, however, this system could not be adopted, as the sand would gradually work itself down. When the weight is great, and the ground soft, concrete forms an excellent bed for a foundation when carefully laid. If the ground is sound, but very sandy, the foundation should be made very broad at bottom, and decreasing by steps to the breadth of the wall, of which it is the support. If the ground is sandy at top, and good clay at a moderate distance underneath, the foundation should be dug down to the firm earth.

If the ground be found defective in one place and good in another, the unequal settlement which would be the inevitable consequence of building upon it in such a state, may be prevented by the use of arches, either inverted or suspended, according to circumstances, and if carefully executed, this plan always turns out successful.

When the soft parts of the ground are under the apertures only, inverted arches are to be turned under such apertures. By this means advantage of one continued base is obtained, for the piers cannot sink, without carrying the arches, and consequently the ground upon which they stand along with them. The whole building will, therefore, sink equally, and no fracture of the walls will ensue.

So much is the use of inverted arches under apertures approved, that they are considered indispensable in all buildings of considerable weight or consequence, even when the ground is not found to be defective. It is sufficiently obvious, that the walls of all buildings, the base of the foundation of which is not actually laid upon the bare, solid rock, will sink a little; and as the pressure of the piers is incomparably greater than that of the low piece of walling under the apertures, the risk is extreme that the resistance of the ground against this low walling will not allow it to sink with the piers, and consequently the fracture of the wall, and probably the breaking of the window sills, will be the consequence. The inverted arches prevent these bad

effects; and as they have so important a service to perform, they should be thrown with the greatest care, closely jointed, and their depth at least equal to half their width.

When the reverse of the preceding case occurs, that is, when the solid parts of a foundation are only to be found under apertures, then piers must be built in these places, and arches suspended between them. It is best to make the middle of the pier rest upon the middle of the summit of an arch. If the pier does not cover the arch, the narrower it is the greater should be the curvature of the latter at the apex. When arches are used in this way, the intrados ought to be clear, that they may have their full effect. The uniform resistance of the ground upon which the piers are erected, is also of greater importance than even its perfect hardness; for if it resist uniformly, the building will sink in every part alike, and remain uninjured.

Foundations on wells.—When works are to be constructed in the beds of rivers, or in other situations where the soil is sand or of a slimy nature, and where water is met with in such quantity that excavation in the ordinary way would be very troublesome, the foundation in this country is usually laid upon wells instead of on wood piles which contrivance may be considered as superseded in India by the use of wells.

The least size for foundation wells is 1 yard inside and $1\frac{1}{2}$ yards outside diameter; the greatest, $1\frac{1}{2}$ yards inside and 2 yards outside diameter. They may be sunk as deep as 12 feet through sand. The wells should be placed from 3 to 6 inches from each other and in rows oblique to the face of the work, in order to avoid the spaces that there would otherwise be between every four. They should spread 6 inches beyond the lowest foundation course. Before the wells are commenced, it is desirable that the ground should be levelled, which is easily done by removing the sand from the whole site of the intended work until the water is reached. The bricks should be cut expressly for the purpose, somewhat narrower at one end than at the other. The first course of bricks is laid on the *well ring*, which is made of three pieces of plank, one inch in thickness and nine inches in breadth joined together. Banian and mango planks are commonly used for well rings but the wood of the country gooseberry (*nelli*) is best, being little perishable under water. Sometimes basket work is used instead of planks below. A well 3 feet inside and $4\frac{1}{2}$ feet outside diameter requires 27 bricks in each course, $4\frac{1}{4}$ inches wide inside, $6\frac{3}{8}$ inches wide outside and 9 inches long—or 40 bricks each $4\frac{1}{4}$ inches wide outside and $2\frac{10}{18}$ inches wide inside. Six courses being allowed per foot, 720 bricks of the latter size will be required for a depth of one yard and for greater depth and size, the number will be proportional. Instead of using well bricks, key bricks 9 inches long, $4\frac{1}{2}$ inches broad at one end, and $2\frac{1}{4}$ at the other, may be used along with common rectangular bricks, which are 9 inches long and $4\frac{1}{2}$ inches broad at both ends. For wells of 3 feet interior diameter, the key bricks must be used alternately with the common ones. If the wells are larger, one common brick additional must be interposed between the key bricks for every yard added to the diameter, or a common brick on edge for every half yard so added.

The bricks are usually laid in clay and when the well is finished, it is bound horizontally with straw ropes from top to bottom, a well

ring is then laid on the top, and the well is again bound vertically with three or four pieces of coir rope passing round both the top and bottom rings. The coir ropes are removed after the well has been sunk.

The well is now ready for sinking which operation is performed by a class of people known as *well-sinkers*. Two well-sinkers, assisted by coolies for removing the soil taken by them from the inside of the well, will sink a small sized well through sand six feet the first day and three feet more the second day. When lumps of harder soil are met with, the progress is slower. In the former case, the well-sinker scrapes the sand with his hands into a basket which he takes with him into the well; in the latter, he must make use of a small mamooty for loosening the lime stone nodules which are often met with in the beds of rivers. Wells of from 3 feet to 3 feet, 9 inches inside diameter, admit only one man to work in them, and there is hardly room in the smaller size. Wells of 5 to 6 feet diameter admit two men; 6 to 8 feet, two or three men; 8 to 10 feet, four or five men who occasionally relieve each other. These large wells are not used in foundations. Sometimes wells are only built 6 feet high in the first instance, and the remaining 3 or 4 feet not added till the first 6 have been sunk; but to avoid confusion, it is better to build the well the full height at once. After the whole, or a sufficient number of the wells have been sunk, they are filled up to within 5 feet of the surface of the ground with a mixture of clay and broken brick, or sand and broken brick, which should be well rammed during the filling. The upper 5 feet of the wells are then removed, and the ground brought to a level and again rammed, and after the water has been got sufficiently low by picottahs and baling baskets, the foundation is commenced with brick cubes, which should have been previously prepared. If these cubes have been carefully made, of a uniform size, the work will proceed with great rapidity; if on the contrary, they vary in size, much time will be lost in levelling each course, and after all, the work will not be good. The cubes may be made with 24 or 12 bricks; the former answer best for the bottom course, but the others, being more manageable may be used afterwards. The cubes are usually laid with sand instead of mortar to fill the interstices between them, as it would be a useless waste to put common lime mortar where it has not an opportunity of becoming dry and setting. The lime is washed out and sand only remains, but if a water cement can be obtained, or made, it is desirable to use it in all building below water, and it should be made use of at least to point or form the exterior joints. After the work has got clear of the water, the cubes may be dispensed with and bricks used.

Wells have occasionally been made of a rectangular shape; the sides being formed with brick cubes, and the corners rounded. They are more difficult to sink than round wells, and require frames inside to prevent their being crushed in. They fill the space better than round wells do, and may themselves be filled in with cubes instead of rubbish.

The lower part of round wells, instead of being formed of single bricks, is occasionally built with pieces of brickwork each 4 courses in height and of which about 10 form a circle, and in building the well

care must be taken that they break joint. Extra expense is incurred in the preparation of these *well cubes*, as they are called, and, wells constructed with them are not much superior to the others.

It will be frequently found impossible to lay the foundation completely across a river at one time, from the difficulty of keeping the water down; the work must then be done in compartments, which will be larger or smaller in proportion to the abundance of the springs. Picottahs and baling baskets will both be required in laying such foundation; by the latter, the water cannot be raised with advantage above 3 feet, and if there is a greater difference of level, two sets must be used. As the greatest height to which the water will have to be raised, will probably not exceed 10 feet, two men will be sufficient for each of the picottahs. The coolies employed in baling usually work by reliefs during the night as well as during the day, and receive double the ordinary pay.

The well-sinkers should always be paid at so much the well, or per foot sunk, and not daily wages. They usually commence work at about 10 o'clock in the forenoon and leave off about an hour before sunset, on the plea that the coldness of the water will not allow them to work longer.

The bricks, forming the upper parts of the wells, will, from their shape, be found very useful in building the curved cut-waters and wing walls of bridges, and indeed, they may be put into other parts of the work, placing the large end of one against the small end of another.

In low swampy ground, after excavating the foundations of buildings to a depth of three or four feet, it is sometimes advisable to sink wells to a further depth of three feet. These small wells may be sunk by the ordinary coolies. In situations where the soil is bad and damp, though wells may not be necessary, it is a good plan to form the lower part of the foundation with one or two rows of brick cubes, there will be then less fear of settlement and the mortar in the cubes having set, the dampness of the soil will not matter. In all such cases, it is advisable to raise the walls up to the level of the basement and fill in the earth between, the first season, and to defer the completion of the building till after the monsoon. Time is thus allowed for the settlement both of the masonry and the earth, and future annoyance from cracks in the walls and sinking of the floors will not be experienced. In building the Scotch Church at Madras, which stands on very low ground, the whole space occupied by the Church was excavated to a depth of 13 feet and wells then sunk under the walls to a further depth of 9 feet. In building annicuts and bridges in Southern India in the sandy beds of rivers, it is not usual to sink the wells to a greater depth than 9 or 10 feet, though the sand may extend to a much greater depth.* In Bengal, wells are often sunk to a depth of 30 or 40 feet, in fact, the practice there seems to be to sink the wells until they reach to firm soil. The necessity for this great depth of foundation is not very apparent, for the scouring of the bed of the river between the piers may be effectually prevented by masonry pavements and retaining walls.

* When, however, firm soil is met with at 11 or 12 feet below the surface it will not be proper in sinking wells to stop short of that depth.

"The process of sinking wells is as follows:—If of brick, the bricks are made purposely for them, and of a shape to fit each other in their breadth in circular layers, like the voussoirs of an arch, of the usual thickness, and about 7 inches long: a little longer as the diameter of the well increases. Before these bricks are laid, a ring of wicker work, of the diameter of the intended well, and as broad as the bricks are long, is placed on the surface, and on it the bricks are carefully laid in horizontal layers, with a little clay mortar, very liquid, between them. A cylindrical wall is thus raised to a convenient height; or if known, as high above the surface as it may be required to sink the wells below it. The cylinder thus formed is then firmly bound together outwardly with hay or straw ropes or twists, wound round it from bottom to the top: this done, the well-sinker gets into the cylinder with a basket, and with his hands chiefly when the mud is soft, sometimes with a *mammootty, (from mun-vutty, earth-digger)* a large short handled hoe, and other fit tools, he excavates the soil from the bottom, and fills the basket, which is then baled up by other workmen on scaffolding above, and handed out of the way. In this operation great care must be taken to excavate *evenly* all round under the wicker ring, that the cylinder may preserve its perpendicularity. The process is thus continued until the cylinder disappears beneath the soil, or until the bottom is found to be of sufficient consistency for the object in view. If the cylinder be not long enough to reach to such a soil, it is raised again, and bound round as before, and the well-sinker continues his work till the object, a good soil or rock, is attained. The well is then filled with brickbats, sand, shingle, small stones or any other substances which will neither *dissolve* nor alter their volume in water, and will admit of being rammed down to a solid consistency.

The wells having been placed as near to each other as practicable, the interstices between them are very limited; but these interstices are also to be filled up and rammed down with the same kind of materials as the wells themselves. The whole space is then levelled to an uniform surface, perfectly firm and impenetrable, on which the masonry of the foundations is established.

The pottery wells are fitted up and sunk like the others, but the cylinders are formed of *baked* rings, formed in frames two or three inches thick, and five or six in height, *in lieu* of bricks. These, however, are seldom used for wells much more than 3 feet; while, on the other contrary, wells even from 12 to 15 feet in diameter, are often sunk with brick in the way described above, and to a very great depth.

The practice of allowing the water to rise over the men is to save the expense of baling, which would be considerable, and also to obviate a greater evil, which would accrue if *baling* were attempted; for the water, forcing itself through the interstices of the bricks, would wash away the mortar and derange the cylinder, which would then fall in. In pottery wells, however, it may be and it is often done: there being less space in these, the sinker is more embarrassed, and would find it difficult to come to the surface for breath if the water were deep.

All wells for water are sunk in the same manner where ever the

nature of the soil admits of it. The clay mortar, in these cases especially, is laid very thin. The dimensions of water wells are suited to the purposes for which they are required, and to their depth. Sometimes the wells are made to diminish in stages as they are sunk, and in this manner wells have been carried to the depth of 50 feet. When required for foundations, the diameters are regulated by the nature of the walls or revetments they are intended to support." An account of St. Andrew's Church, Madras, by Major Thomas Fiott deHavilland.

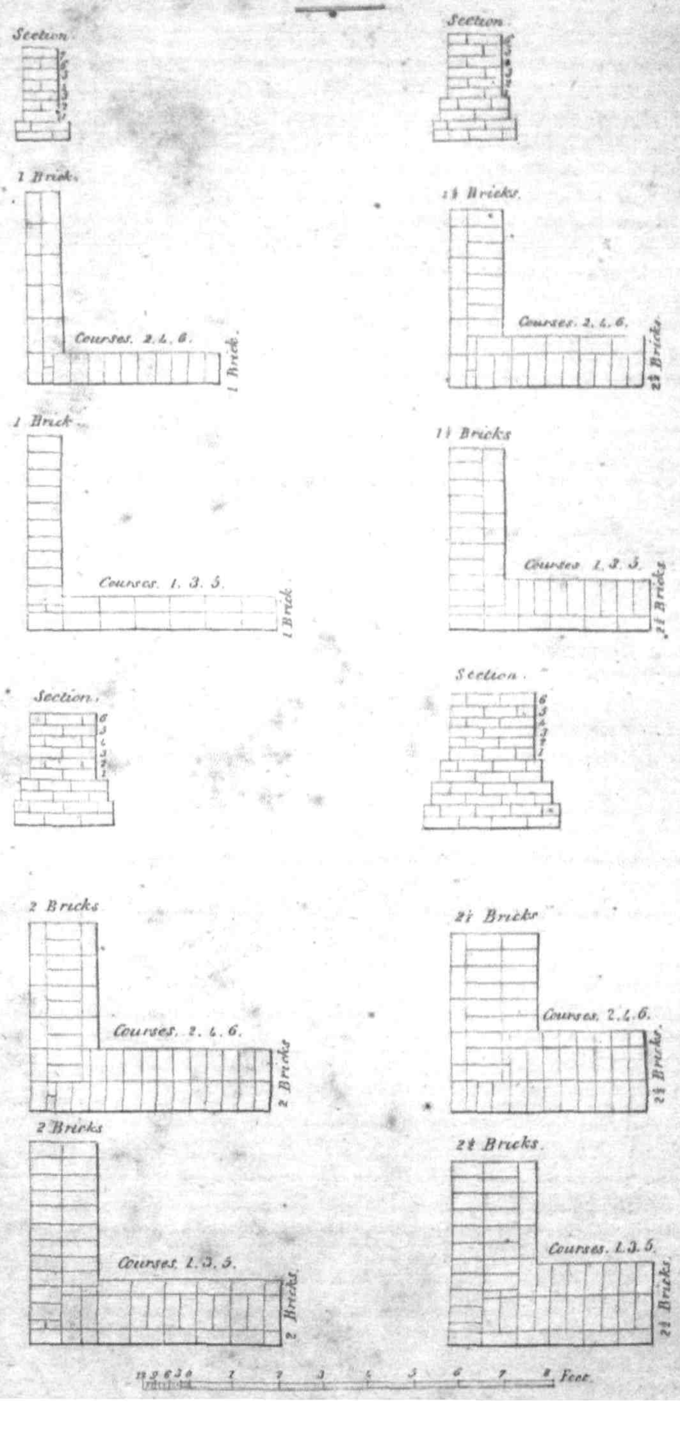
Footings.—The bottom courses of the masonry of the foundation are usually extended beyond the face of the superincumbent work. The object of these spread courses, or *footings*, is to distribute the weight of the structure over a larger area of bearing surface, by which the liability to settlement, from compression of the ground, is much diminished. The footings of brick walls should be well bonded into the body of the work, and laid in double courses with projections on each side of a quarter of a brick, as shown in Plates XIV and XV. In building large masses, such as the foundations of piers and abutments of bridges, it is best to give very little projection to the footing courses and to carry up the work with a succession of slight offsets. In a perfectly unyielding soil, as rock, there is no occasion for footings, but in compressible soils, the base must be broad.

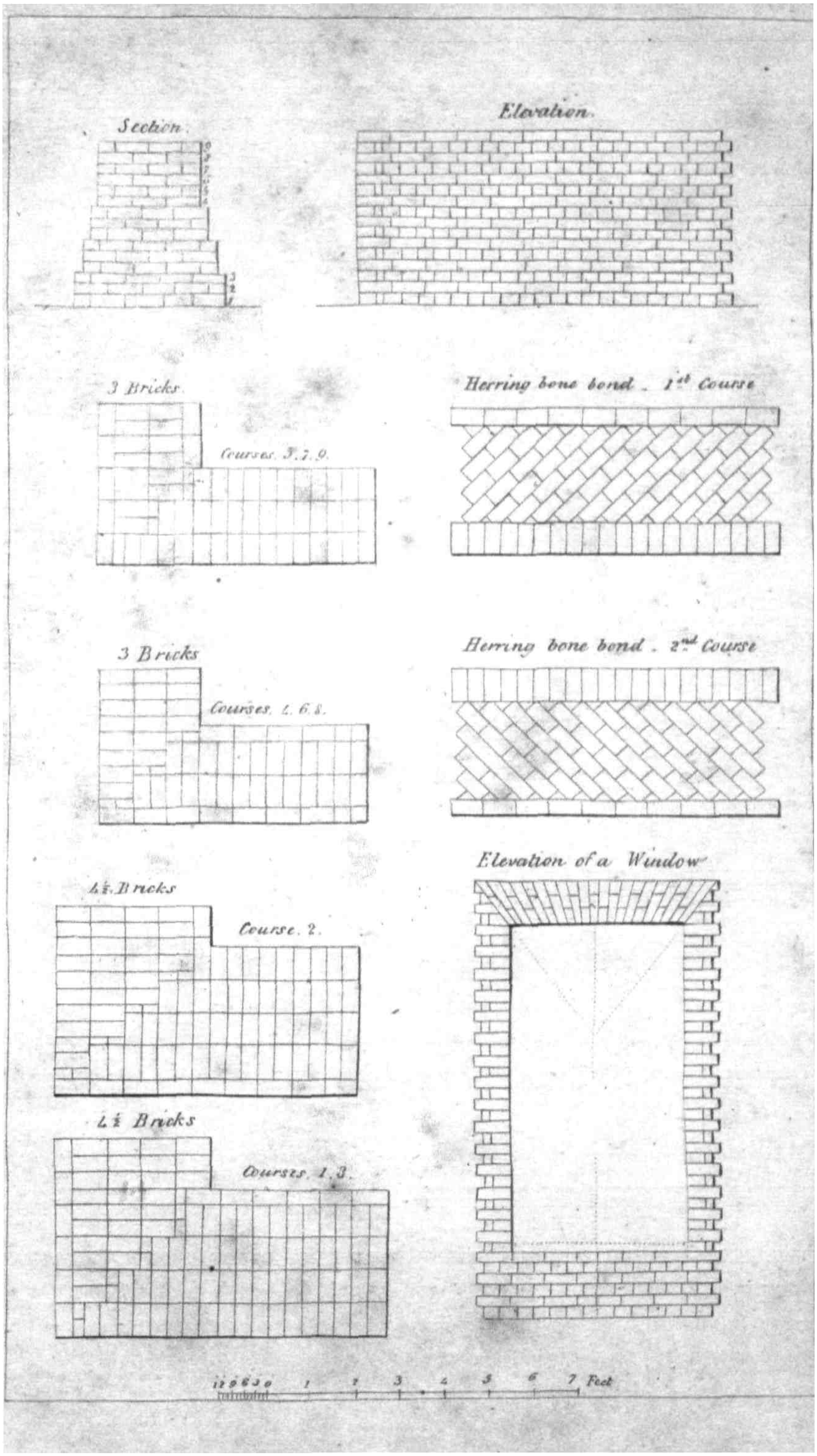
The foundations of houses, *in this country*, are usually made uselessly deep and not sufficiently broad at the base, and this is one reason why so many buildings have cracked walls. It is a good rule to make the foundation double the breadth intended for the superincumbent wall, and the contraction of it should be made alike on both sides. It is also a very common practice, with native bricklayers to construct the foundations almost entirely with fragments of bricks, and many of them ill-burned. Common sense would dictate the employment of the best materials and workmanship in the foundation, for, on it depends the stability of the whole structure. If there be any difference in the quality of the bricks, the strongest and closest, which are least liable to imbibe moisture, should be selected for foundation work.

Concretes.—*Concrete*, is a composition of small stones, bricks or rubble, and sand, with lime (ground to powder), generally in the proportions of from $\frac{1}{5}$th to $\frac{1}{9}$th of lime, to one of the mixture of rubble and sand. After the ingredients are thoroughly mixed and water has been added, the concrete hardens into a solid mass.

Some authors draw a distinction between concrete and béton: regarding *béton* as being made with *hydraulic* mortar, and concrete prepared from non-hydraulic limes. Others again consider the difference to be in the mode of mixture: when the cement or lime is first mixed with sand, and treated as a mortar before being incorporated with stone or gravel, it is termed *béton:* and when that preliminary operation is omitted, it is called *concrete*. *Béton* may thus be said to be the French process, while *concrete* is the analogous, but clumsy operation, as originally followed in England. But such distinctions are too nice for practical purposes, and the names concrete and béton may be considered synonymous.

BRICK WORK


Section
1 Brick
Courses. 2. 4. 6.
1 Brick
1 Brick
Courses. 1. 3. 5.
1 Brick
Section
2 Bricks
Courses. 2. 4. 6.
2 Bricks
2 Bricks
Courses. 1. 3. 5.
2 Bricks
Section
Courses. 2. 4. 6.
Courses. 1. 3. 5.
Section
Courses. 2. 4. 6.
Courses. 1. 3. 5.
1 2 3 4 5 6 7 8 Feet


Section.
Elevation.
3 Bricks.
Courses. 5. 7. 9.
Herring bone bond. 1st Course
3 Bricks
Courses. 4. 6. 8.
Herring bone bond. 2nd Course
Elevation of a Window
4½ Bricks
Course. 2.
4½ Bricks
Courses. 1. 3.
12 9 6 3 0 1 2 3 4 5 6 7 Feet

Concrete should not be made from rich limes, unless such as are improved by being combined with powdered brick, &c. If, however, circumstances compel the use of rich lime, it must be reduced to the finest powder by slaking or grinding, and evenly sifted through a very fine sieve: then mixed with a proper proportion of ballast (gravel, sand, &c.,) and wetted not overmuch, but sufficiently for its complete conversion into a hydrate. The poor or hydraulic limes are better adapted for concrete purposes, in consequence of the amount of silica which they contain. They also require to be reduced to the finest powder by grinding or slaking.

In order properly to apportion the quantity of lime necessary to be used with the ballast, it will be well to ask this question: What are you in reality doing when forming a mass of concrete? or, rather, what ought to be done? To this the answer must be, a stone wall; in a manner, it is true, possessing advantages peculiarly its own, but still a stone wall. The pebbles, then, are the materials with which it is to be built, and must be regarded only in that light, so that in considering the quantity of lime necessary to be added in order to form a proper mortar wherewith to unite them, regard must alone be had to the sand contained in the ballast, and according to the quantity and quality of that ingredient must be apportioned the lime. It is true, that upon the proportion borne by the pebbles to the mortar, the strength and goodness of the concrete materially depend; but this, except under peculiar circumstances, must but little interfere with the preparation of the mortar; it is another question, separately to be considered.

Ordinary good lime will form a most excellent mortar when mixed with three times its own quantity, by measure, of sand; and although it is quite certain that if it be well burned, ground, and used fresh—and this it must always be for concrete—it will make excellent mortar when mixed with four of sand, even better, if the lime be powerful, than with less, this may serve as a generally admitted good proportion. With respect to the amount of stones essential to a good concrete, it is generally maintained by those practical men who have thought upon the subject, that it should be double that of the sand by measure.

In the formation of concrete, solidity is the great end to be attained. We know very well that, although a pit appears to be filled with large stones, the interstices necessarily occurring would still admit a great quantity of smaller stones, and that even then sand to a large amount might be introduced without occupying more space. Variety of size in the stones employed, and consequent need of sand is, therefore, of importance even in this point of view, to say nothing of the necessity for its presence in the formation of mortar, whereby the stones are to be connected. No effect will be produced by the lime alone; it is from its mixture with sand that the properties of mortar alone result, and, it is much better that it have too much of this ingredient than too little.

It is hardly necessary to observe that if pit gravel be used, it should be well washed in order to free it from all dirt or impurities, and a due quantity of clean, sharp, river sand, if needed, be added to it, care being taken that the sizes of the stones are as various as possible.

The methods of mixing and applying concrete are several, each having its advocates and opponents. The one most generally employed

is thoroughly to mix the lime previously ground, with the ballast, in a dry state; sufficient water being then thrown over it to effect a perfect mixture; it should be turned over, at least twice, with shovels or mamooties,—if oftener so much the better—and used *instantly*. Sometimes, instead of mixing the materials in a dry state, the ballast is spread out and wetted with water, then covered with the proper proportion of ground lime, and turned over as before.

The concrete after being thrown down into the trenches, or intended site of the building, it is customary to keep a man constantly employed in levelling or puddling it as it is termed; this, if it be done, should follow instantly after the concrete is thrown in, for, if the concrete be first allowed to set, much harm will be done by disturbing it.

Temporary Dams.—Before a work is commenced in the bed of a river, it will often be necessary to construct a temporary dam. If the work is an annicut, and the supply channel from the river has been already dug, the dam may be thrown completely across the river as the channel will draw off the water, which collects above the dam, to be used in irrigating lands for which the permanent annicut is intended. In the case of a bridge, it will not be always necessary to make this dam from bank to bank, as it is liable to be suddenly carried away by a fresh in the river; but in any case, it will be advisable to surround about a third or a fourth of the site of the bridge or annicut, with a second dam, formed with the earth taken from the foundation, so that in the event of the first dam being breached, there will be space for the water to run off without injury to the work actually in progress. As soon as one portion of the foundation is raised as high as the bed of the river, another should be commenced, and no part should be raised higher till the whole has been brought to that level, after which, with proper precautions, a little danger is to be apprehended from floods. Dams made with sand can never be water-tight, but they will often serve a good purpose. In order to protect them from the action of the waves, stakes should be driven in front, behind which, date mats and branches of trees may be placed. The making of these temporary dams is, of course, a very simple operation, except at the part where the stream is running, which is left till the last, and the closing of the opening requires a little management. It is most usual to prepare beforehand in the bed of the river a number of fascines made of clay rolled up in branches of trees, and bound round with straw ropes. Stout stakes are placed across the stream, to the front of which the fascines are rolled, and as many coolies as possible having been collected, the bank behind is rapidly filled in. The difficulty is obviously in proportion to the quantity and velocity of the stream, but Indian rivers, being nearly dry in the working season, offer great facilities for the construction of these dams.

After the dam is made, a lake is gradually formed above, and provision must be made for drawing off the surplus water by a channel, which may either fall into the river at a point below the site of the bridge intended work, or be led to supply some tank or irrigate lands. A channel can in some cases be dug which will draw off so much water that a dam becomes unnecessary.

CHAPTER IV.

MASONRY.

The term *masonry* is, in England, used to designate the art of building with stone, as well as the work itself when executed. The workers on stone, called masons, are a different class of artificers from those who work in brick and called therefore bricklayers. In this country, the distinction does not exist, both brick work and stone work are done by the same individual.

In a wall of masonry, the term *face* is usually applied to the front of the wall, and the term *back* to the inside; the stone which forms the front, is termed the *facing*; that of the back, the *backing*; and of the interior, the *filling*. The term *course*, is applied to each horizontal layer of stone or brick in the wall. The mass formed by bricks, laid in concentric order for arches, is also called a *course*. The divisions between the stones in the courses are termed the joints. The upper surface of each course is called (with reference to the course immediately above) the *bed*. The arrangement of the different stones or bricks in each course, is termed the *bond*. Bricks or stones, having their lengths in the thickness of the wall, are termed *headers*, and those which have their lengths in the length of the wall are termed *stretchers*.

SECTION 1.—Stone Work.

Cut Stone.—Masonry of cut stone, when carefully made, is stronger and more solid than that of any other class; but, owing to the labor required in dressing or preparing the stone, it is also the most expensive. Frequent examples of this kind of work are to be met with in the Madras Presidency. Many Pagodas, Choultries and Mundapums are built entirely of cut stone. The workmanship in these buildings, if closely examined, will generally be found to be very indifferent, owing to which, as well as to the circumstance of their being rarely repaired after the death of their founders, they go to ruin much sooner than might be expected from their substantial appearance. Cut stone is much too expensive to be adopted to any extent in public works, except as a facing or covering to brick or rubble work, and it is then called *ashlar masonry*. In ashlar work, all the stones of a course should be of exactly the same height, but it is not necessary that the height of every course should be the same. All vertical joints should be square or at right angles to the face, for at least 2 inches from the face, beyond that, they may widen a little. The upper and lower beds of every stone should be square with the face and consequently parallel with each other. It is neither usual nor necessary to dress the backs of the stones. The vertical joints of

a course should fall on the middle of the stones in the course below. Bond stones of a length to reach at least one foot into the backing, should be introduced into every course. Every bond stone should, if possible, be placed in the middle between those in the course below, and the quantity of these stones should be not less than a sixth of the face of the wall. A great deal of cut granite is now taken for public works from ruined pagodas and choultries; if the stones are standing in the wall, they should, previous to their removal, be carefully numbered, that they may without difficulty be placed in the same relative position, otherwise, much expense will be incurred in again fitting them together. A partial re-arrangement of them, however, will often be advisable, as nearly all the stones in the ashlar fronts of Native buildings are placed with the largest surface outwards, and they consequently have but a feeble adhesion to the brickwork inside. To build an ashlar faced wall, the facing stones must first be set accurately in their places bedded in mortar, and adjusted to their positions by the line and plumb rule, which, being done, the backing succeeds, and this is building a wall in bricks or rubble stone immediately behind the stone facing and in close contact with it, taking care to fill in between the stone facing and wall with mortar. This wall proceeds horizontally until it reaches the same height as the first course of stone, consequently, if the backing is to be of brickwork, the height of the facing stones ought to be such as may agree exactly with a certain number of courses of brickwork, three or four courses for example. Native bricklayers do not usually observe this rule. The second course of facing stones is then set upon the former course, and the backing built up as before. The mortar joints should be exceedingly thin, and the mortar for cut stone work should be prepared in the way described in a previous chapter.* After the stone has been dressed, it should be handled very carefully in order that none of its sharp corners or angles may be chipped off. The expense of the work will be very much increased by using stones of small size, for the smaller the stones the greater will be the surface of joint to be dressed. The difficulty of handling and raising large stones, of course, puts a limit to the size.

When a large quantity of cut stone work is to be executed, it is very desirable, in order to save time, that the stones should be fitted together before they are wanted. In the case of a floor, like the apron or top of an annicut, it will be sufficient to mark out the size on the bank of the river, the stones should then be fitted and numbered and they can be placed again very expeditiously in the same relative position. When facing for a bridge pier is to be prepared, its shape must be carefully marked out on level ground; the first course of stones is then to be fitted and the space within filled in with sand; the next course of stones is then to be placed, and the space within filled in as before, to prevent the stones falling in. The stones must be numbered previous to removal.

The use of cut stone is restricted to the casing of bridge piers in some rivers, which bring down trees during floods, when, it is necessary that the cutwaters, on the stream side at least, should be

* See page 50.

faced with hard stone; the aprons of high calingulahs and annicuts; sides and flooring of large sluices; covering of culverts and drains, in this case accurate fitting is not required; and the flooring of some public buildings, such as churches, hospitals, &c.

Ashlar floor.—The under surface of stones used for flooring, is seldom dressed smooth. A levelling course of bricks should always be placed under the stones, which should be firmly imbedded in a mixture of broken brick or stone chippings and mortar, disposed so as to fill up the irregularities in the stone. The stones are either equal squares of about a foot, or rectangular of different sizes. In the aprons of calingulahs and annicuts, the joints in the direction of the breadth should be continuous, but not so the others.

Rubble Stone Work.—This description of masonry may be extensively used in this country, and if carefully executed, possesses all the strength and durability required in a structure of an ordinary character, while its cost is often only half that of brick work. When the stones are on the spot, or can be procured within the distance of a mile, the price per cubic yard will be about a Rupee, and every mile of carriage adds 2 Annas to the cost. The stone used for this work should be prepared simply by knocking off the sharp weak angles of the block; it is then cleaned from dirt and wetted before being placed on its bed. The bed is prepared by spreading over the top of the lower course an ample quantity of good ordinary tempered mortar, into which the stone is firmly imbedded; the interstices between the larger masses of stone are filled in by thrusting small fragments and chippings, or pieces of well burned brick, into the mortar. The best stones should be selected for the edges and more particularly for the corners, for the latter, it will be sometimes advisable to use cut or roughly dressed stone. Slab stones, or those which divide naturally into plates, will produce stronger and better work than boulders or stones that present rounded surfaces to each other. Rubble stone work answers admirably for the side walls of road tunnels, piers and abutments of bridges, calingulahs (except for the apron when the water falls from a great height), heads of river channels, revetments of large tanks, and in short, should generally be used in those districts where stone is easily procurable.

The cement used by the mason, for the ordinary purposes of walling, is mortar, and as this subject has already been treated upon rather at length, a few remarks in this place will suffice. For the joints of hewn stones, the mortar should be much finer than the bricklayer requires;* and sometimes a mixture of oil putty, or very thick white lead paint, is used as the cement.

The cement used in setting column stones, is mostly oil putty, or white lead mixed with chalk putty, or fine mortar. Sometimes columns are set upon melted lead; in this case, the lead should not be quite equal to the column in diameter, but so as to leave a narrow ring externally, which must be filled with oil putty.

SECTION 2.—Brick Work.

Bricklaying is the art of building with bricks.

* See note, p. 50.

The different descriptions of brickwork practised in this country, named with reference to the kinds of materials used, are :—

Brick Work in clay—when 1st and 2nd sort bricks and mud or clay are used.

Brick Work in Chunam—when the same class of bricks and lime mortar are used.

Brick Work in Mud or Clay.—To save expense, the natives are in the habit of building with brick in clay, and even the largest houses at Madras are so built, but the use of clay instead of chunam is not frequent in public buildings. Brick in clay work is by no means deficient in strength; the principal objection to it arises from the ready passage which the mud affords white ants to the roof. This may to a certain extent be remedied by setting some of the upper courses of bricks in chunam. Compound walls are frequently built with brick in clay, but the practise is bad, for such thin walls being exposed to the weather on both sides are constantly in want of repair. A compound wall of great length should not be of uniform width; it will stand better if furnished with pilasters, projecting a quarter of a brick on each side, at intervals of about ten feet.

Mud Work.—Walls of mud alone, are also of frequent use. The walls of huts are formed entirely with mud, and such buildings will be required in the vicinity of large works, both for storing materials and tools, and for sheltering coolies, who may have come from a distance. The most suitable earth for mud walls is a mixture of clay and sand, which when required for building, must be tempered into a stiff paste. The walls should be raised only about a foot at a time and successive portions not added till those below are dry. The thickness of the walls will be from 9 inches to 2 feet, according to the height, and should be somewhat less at top than at bottom. The durability of these walls, and also of mud floors, is much increased by their being occasionally smeared with a mixture of cowdung and water. The roof is formed roughly and thatched with grass or palmyra leaves. There is another method of raising mud walls, which may be practised in the vicinity of jungles. The shape of the house having been marked out on the ground, holes from two to three feet deep are made in the angles and also in the line of the walls, about two or three feet asunder, except where the doors and windows are to come where the interval must be greater. Trunks of straight trees, about six inches in diameter, and of the required height, are then firmly fixed in these holes and connected at top by wall plates, having holes pierced in them to receive the tenuons cut on the top of the posts. Split bamboos in pairs are then tied (by vegetable fibre called *nar*) on each side of the uprights, parallel to the ground, about six inches apart all the way up to the top. The wall is next filled in with tempered clay so as to cover all the wood work, and may be raised ten or twelve feet in a couple of days. It is then plastered with a mixture of clay and sand, washed with cowdung water, and lastly white washed. A few bricks will be required to place round the door and window frames, and the assistance of a bricklayer will be required for this part of the work, but the rest may be done by ordinary coolies and a village carpenter.

Neat bungalows may be built in this way very cheaply and they will last many years.

Brick Work in Chunam.—With good brick and mortar, this description of work offers great strength and durability, arising from the strong adhesion between the mortar and the brick. In using bricks for building purposes, an even surface or foundation is first prepared, which should be truly level in each direction. The first course of bricks is usually laid without mortar, the bricks being placed with their broadest surfaces upwards and downwards. This course being finished, mortar is laid over its upper surface to bed the bricks of the next course, which must have their vertical joints also filled in with mortar, and in this manner the work proceeds upward until finished.

Straight walls are built by first setting out the *quoins* or angles of the building on the ground, and then straining a line from one point to the other, which will, of course, be straight. The line is fastened at its two ends to wooden pegs, which are stuck in the soft mortar joints. In order to be able to fix this line in its proper place, two quoins of the building must be carried up three or four courses higher than the intermediate work, and the lower courses must be made truly level by the application of the bricklayer's level. That done, the work may proceed with any required rapidity, all that is necessary being to examine that the faces of the wall are truly perpendicular, which is done by the application of the edge of a plumb rule at every course, and an occasional examination of the level state of the courses, which ought to be made at every fifth or sixth course. When walls are built circular, or curved on the plan, it is evident they cannot be carried up by the line and pins which can only give *right* lines. Curved work must, therefore, be carried up, by what are called *moulds*, and these are merely thin boards, 3 or 4 feet long, one edge of which is cut into the curved form the wall is intended to have; and they are used in the manner of a ruler, being applied upon the upper surface of every course of work at the commencement, when the bricks or stones are placed in exact coincidence with its curved edge. When the first two or three courses are laid, the mould will only need occasional application, if the wall is to be perpendicular, because the plumb rule, used in the ordinary way, will be sufficient to carry up the work correctly from the bottom courses, if properly laid. When curved work is of small radius, it will require all whole bricks to be cut into wedge shapes, or they must be so moulded for the purpose.

Round pillars are usually built with quadrant shaped bricks, and when they are of considerable height, circular slabs of stone of the same diameter as the pillar, and about three inches thick, are introduced at every four or six feet to prevent the pillars splitting.

As a general rule, the brick work or masonry of a building ought to be carried up as nearly as possible of one uniform height all round, which is easily effected by having workmen stationed on every side who work simultaneously; or, when hands are scarce, the slower process of working the same level course, or nearly so, all round the building, should be adopted, and no one part should be permitted to rise more than a foot above the others, by which means an equal weight will be thrown

upon every portion of the foundation and lower work, and no one part will have a greater tendency to sink or settle than another.

As brick has great avidity for water, it should be steeped in water before being used. By taking this precaution, the mortar between the joints will set more firmly than when laid dry when it imparts its water to the dry brick, which it frequently does so rapidly as to render the mortar pulverulent when it has dried. Another reason for the bricks being dipped in water is that they are generally covered with dust, which intervenes between them and the mortar, and prevents adhesion. The ill-effects of using bricks, that have been exposed to a hot sun for several hours, are very apparent in this country; for how common it is, in examining lately constructed works, to knock off some of the bricks and find the mortar like dust. Lay two bricks on a bed of mortar, one wet and the other dry, on taking them up a few days after, the wet brick will bring up its bed of mortar with it, while the dry one will come up without a single particle of mortar attached to it. On these occasions, the complaint is often made that an excess of sand has been used with the chunam; now the truth is, that the chunam will often bear a larger proportion of sand than is mixed with it, and the reason of the mortar being found in so unsatisfactory a state is, that the heated bricks absorbed the water so rapidly, that the mortar had not time to set properly. It must be observed, however, that mortar, which seems to have not the least adhesion the first day, or two, often becomes in the course of time perfectly solid and adhesive.

When the practice of steeping the bricks in water is rejected as too troublesome, the sprinkling of each course with water may be considered the easiest substitute for that operation.

Brick bond.—The bond, used in brick work, deserves a great deal of attention, but in this country usually receives very little, and to this circumstance is to be attributed the frequent cracks and splittings of walls into two thicknesses, they being often built with a continuous joint in the middle from the bottom to the top and from end to end—that is, in two distinct portions. The partition walls of houses are often built separately from the others, instead of being bonded into them, and after a little while, a crack makes its appearance in each corner. The object for which buttresses are built is, for the same reason, to a great extent neutralized.

The object of bond in brick work is to preserve a transverse and longitudinal tie between every portion of the walls, so that its stability should be as great as possible independently of the cohesion of the mortar, which when added will then render the wall as strong as the materials will admit of its being made. Each joint in every course of brick work should, therefore, be covered by the middle of a brick in the course above it which besides causing each brick to be the summit of a pyramid of bricks, whose base is continually extending to the bottom of the wall, will prevent any brick from settling, except by breaking. A transverse tie must also be formed between the front and rear of the wall, by means of a sufficient number of headers to cross the joints which run lengthways, and thus prevent these joints from dividing one thick wall into two or more thin ones, which would be

apt to split apart. As settlements are more likely to take place longitudinally than transversely, from variations in the compressibility of the foundations, differences in the thickness of mortar joints, unequal bearings, &c., it is evident that more bricks should be laid as stretchers than as headers, and also that these last be carefully arranged so as to cover the joints of the stretching courses.

English bond is a continuation of one kind throughout the same course, and consists of alternate courses of headers and stretchers, the headers serving to bind the walls together transversely and the stretchers longitudinally. This kind of bond is not proper for the walls of houses, because the joints are not sufficiently broken, for two stretchers occupying as much space in the thickness of the wall as one header, a straight joint would run through the whole length and height of the wall. In Plates XIV and XV, is shown the proper method of laying the bricks, in the alternate courses, for walls from one to three bricks in thickness. The longitudinal bond of the walls is only 2¼ inches, or one-fourth of the length of a brick of 9 inches, and is obtained by introducing *closers* 2¼ inches broad, in the angles as shown in the Plate. It will be seen that in one course, the closers are introduced in one of the walls forming the angle, and in the following course, in the other wall, so that a continuous joint, in the prolongation of the inner face of the wall, occurs only in alternate courses; but if there were no closers, the joint would be continuous from top to bottom. The appearance that English bond has in the face of a wall is shown in the elevation (Plate XV). It will be seen that the vertical joints in the alternate courses are exactly over each other, so that if a long plumb line were fixed in any vertical joint of a piece of work at its top or upper course, that line would also cover or pass over the vertical joints in every alternate course below it. The object of making the length of the brick exceed twice its breadth by the thickness of the mortar joint will now be apparent, for unless each brick (laid end to end) were exactly equal to every two bricks placed side to side with the necessary quantity of mortar between them, there would be no regularity in the face of the wall.

Broad masses of masonry, such as the piers of bridges, may be carried up in alternate courses of headers and stretchers, taking care that no two vertical joints shall occur in the same line over each other in two contiguous courses, and the bricks should not be placed with their whole length along the side of another, but so that the end of one may reach to the middle of the others which lie contiguous to it, and two rows laid diagonally, or in *herring bone bond*, may occasionally be introduced. The thickness of the joints should not exceed a quarter of an inch.*

Not second in importance to bonding in brick work is, that it be perfectly plumb, or vertical, and that every course be perfectly horizontal, or level, both longitudinally and transversely. The lowest course in the footings of a brick wall should be laid with the strictest attention

* *Bricks that have been carefully moulded on a table may be laid with very thin* mortar joints, but those of an irregular shape require to be bedded in a considerable thickness of mortar, which, besides being prejudicial to strength, causes the low priced irregular bricks to be in the end dearer than those that have been moulded on a table.

to this latter particular; for the bricks being of equal thickness throughout, the slightest irregularity or incorrectness in that will be carried into all the courses above it, and can only be rectified by using a greater or less quantity of mortar in one part or another, so that the wall will, of course, yield unequally to the superincumbent weight, as the work goes on, to its great detriment.

Good examples of brick work are rarely met with in this country, for the custom of plastering all walls, both on the inside and outside, gives encouragement both to the manufacture of bad bricks and a bad method of laying them. Besides, what with the careless way of packing the bricks in the clamps and of removing them thence, the jolting in the bandies, and the throwing them down near the work, very few whole bricks find their way into a wall, and fragments cannot be laid by any rule. The native bricklayers, merely look to carrying up the wall tolerably square, and do not trouble themselves about the bond at all. There can be no objection to plastering the inside of walls of houses; indeed, a method of finishing them more suited to the climate could not be found, but outside plastering might, in many cases, be dispensed with. It gives bridges and similar structures an exceedingly paltry appearance which is much increased by trifling ornaments, such as the imitation of stone work and similar shams.*

From their being no fixed dimensions for bricks, the thickness of walls is given in feet and inches, and this always leads to very bad work; for, to make up the required thickness, either very large mortar joints are made, or the space is filled in with fragments. With the dimensions that have been recommended, 2 bricks will be a proper thickness for the exterior walls of houses, and when there is to be an upper story, 2½ bricks. Partition walls may be made a brick and a half thick, and for some a thickness of one brick will be sufficient.

In effecting repairs in masonry, when new work is to be connected with old, or when a continuous wall is built up in portions, the ends of each portion should be, what is technically called racked-back, or built in steps, and the wedge-shaped piece, forming the junction should not be built, till both portions are thoroughly set; no crack will then appear at the junction.

Construction of Arches.—Brick is the material most usually employed in the construction of arches in this country: the principles of construction are the same both in stone and brick, but in using of the former, every voussoir has to be cut to an exact form, with a pressure proportionate to the weight of an arch and its superincumbent load. In all arches, the joints should be prolongations of the radii of curvature, and, therefore, in semi-circular and segmental arches, the joints should be directed to the centre of the circle of which they form part, and in elliptical arches, the direction of the joints, at any point in the curve will be the prolongation of a line bisecting the angle formed by two lines from the foci to that point. As it will be tedious and in many cases impracticable, during the actual construction of arches, to find the direction of the joints in the above way, it is recommended to

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* See p. 49, *On Plaster*.

have a light wooden frame, shaped to the intended curve, with nail on the *arc* at intervals and corresponding nails at ascertained distance on its *chord;* then, if the frame be placed against the side of th centring, a line passed from one nail to the other and drawn tight t pass the extrados or back of the arch, will show the direction of th joints. This frame will be required at the time of constructing th centring, and it will be sufficient if it is the size of half the arch. Th Maistries have a simple instrument for finding the direction of th joints, which is nothing more than two pieces of wood at right angle to each other, in the shape of the letter T inverted, or of the letter L with the under surface of one piece planed away to correspond with portion of the intended curve, or having two projecting points as show in Figs. 7 and 8, Plate XVII, and this being placed on the edge of th centring, the piece at right angles shows the direction of the joints.

The planes of the joints of each course of voussoirs between th heads of an arch are made continuous, each of these courses bein termed a *string* course, and their joints *coursing* joints. The planes o the joints along the curves of right section are not continuous, bu break joints; the stones which correspond to two consecutive series o these joints being termed a *ring* course, and its joints *heading* joints By this combination of the ring and string courses, the fitting of th blocks, the settling of the courses, and the bond are arranged in th best manner.

When arches are built with the ordinary rectangular bricks, lai so that the joints are continuous from the soffit, to the back of the arch it is evident, that, however close the joints might be at the soffit, the would be very open at the back, and the strength of the arch wi depend on that of the mortar in the joints. To remedy this defect, i is usual in England, to build arches up to 40 feet span in concentri rings, each half a brick thick: the bricks are all laid on edge and th joints of the several thin arches do not correspond. It is evident that by this mode of construction, a greater quantity of the solid materia comes into the back or outer ring of the arch than into the lower one and, if they have been bonded together into one arch, all that differenc must have been made up with mortar. There is an objection to thi plan, viz., that the concentric curves, being only kept together by th mortar between, might separate should any motion take place in th arch, and there will be danger in the rings not settling equally, o account of the upper rings having more bricks and more joints in them than the lower ones, and should this occur, the pressure may becom transferred to a single ring while it is thought to be borne equally b them all and the arch may in consequence fail.

It will be better to place the courses of bricks from side to side o the arch alternately on end and on edge (using all whole bricks an the same bond as in ordinary walling) and to avoid the thick joints a the back, bricks might be moulded with reference to the position they are intended to occupy in the arch. Moulds will be required both fo the bricks laid on end and those laid on edge, two or three for each. These moulds should be bevelled off so that their slopes should converge in the ratio of the radii of the curve about to be constructed. This might easily be arranged by reference to the plan, and better work would be obtained. This may be thought an unnecessary refinement,

but, it must be remembered, that when a large number of bricks are to be made for a bridge, moulds can as easily be made of one shape as another, and the cost of the bricks will not be influenced by the shape of the moulds. Another and simpler plan would be to lay several courses of bricks with the joints of an equal thickness from the soffit to the back, then, to correct the direction of the joints, the next course might consist of well bricks laid with their breadth parallel to the axis of the bridge. The next set of courses may then be laid as the first set, and the error of direction corrected as before. Of course the flatter the arch, the less the number of these correcting wedges will be required.* Or a quantity of thin well burned tiles might be prepared for the purpose of filling in the open joints at the back.

In large arches, it is of greater importance that the joints should be close than that their direction should be *perfectly* true. The great sinking of some arches, on the removal of the centring, is almost entirely due to the thickness of the mortar joints, which has occasionally exceeded 2 inches in parts of the arch, whereas, it should not be more than three-sixteenths of an inch.† In small brick arches, built with

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* An arch of 36 feet span and 9 feet rise, of which the radius is 22½ feet, will require 32 courses of bricks 3 deep at each haunch, then 15 or 16 courses 2½ deep, and *for the crown,* 116 *courses* 2 bricks *deep—total* 210 *courses in the intrados, which is* 41 feet, 8¾ inches long, measured round the curve. At 9 inches from the intrados, the parallel curve will be one-thirtieth longer. In order, therefore, that the courses should radiate properly in each course, the bricks should be one-thirtieth thicker at one end than at the other at 9 inches; one-fifteenth at 18 inches, one-tenth at 27 inches, or at 3 bricks length from the intrados. But it is sufficient to correct the radiation every now and then. To do which, it is necessary to have some bricks made of the following dimensions—length 8¾ inches, thickness 2 inches, breadth at one end 4¼ inches, at the other 2 inches. Or they may be made 2¼ inches thick at one end and wedge shaped, 4¼ inches broad. The former should be set on edge and the latter laid flat—the former kind will, perhaps, be the best, and should be introduced at every thirtieth course and should also form the key. Thus, if the arch, of 36 feet span, consist of 210 courses in the intrados, there will be one course of key bricks at the crown, and three more on each side—viz., at the thirtieth, sixtieth and ninetieth courses from the crown, the last being fifteen courses from the springings of the arch. At each of the ninetieth courses, or counting from the springings fifteenth courses, 3 bricks thickness will be added to the extrados, the arch being 3 bricks thick; at the forty-fifth, 2½ bricks, the arch being 2½ bricks thick in that part; and at the seventy-fifth and a hundred and fifth, or key, courses, 2 bricks will be added to the extrados. If the arch were of smaller span, and of a different form from the segment rising one in four, the difference of the length of the intrados and of the parallel curve to a radius longer by 9 inches, might not be one-thirtieth of the intrados. Thus, if the span be 36 feet and rise 9 feet, the intrados will be 41 feet 8¾ inches, the parallel curve 43 feet, 1½ inches, and the difference one-thirtieth. If the span be 18 feet and the rise 4½, the intrados will be 20 feet, 10⅝ inches, the parallel curve 22 feet, 3 inches, the difference one-fifteenth, and generally the fraction is the radius of the curve *divided by nine inches; whence is derived the following rule.* Divide the radius of the curve by 9 inches, or for every foot multiply it by 4 and divide by 3. Lay the courses of bricks parallel to one another until their number is one less than the quotient thus obtained, and then introduce a course of key bricks, in order that at each of these intervals, the radiation of the voussoir lines may be corrected. For example, in an arch of 60 degrees, the span is 1½ yards consequently, the radius of intrados is 1½ yards. This divided by 9 inches gives a quotient of 6, and a key brick should be *introduced at every sixth course.* If the arch were 1 yard span, a key brick would be required at every fourth course. If the arch were 40 feet span and semi-circular, its intrados would be $\frac{40 \times 11}{7} =$ 62 feet, 10 inches $=$ 335 courses (each brick with the mortar joint being 2¼ inches): now $\frac{20 \times 4}{3} = 26\frac{2}{3}$ courses, the interval to be kept between the key courses.—*From Notes of the late Captain Best.*

† To obtain close joints with bricks that have been moulded on the ground, they must be rubbed. If the bricks have been moulded on a table, this rubbing will not be required.

good mortar, it will not be of much consequence if the joints are a little thicker at the back than at the soffit. The two sides of an arch should be begun and carried up simultaneously, otherwise the centring will be subjected to an unequal pressure which might cause it to change its form. When the arch has advanced to about 3 feet of the crown on each side, the courses of bricks should be guaged, but as, notwithstanding this precaution, it will sometimes happen that the space left for the key brick is greater than the thickness of a brick, it will be a good plan, in order to avoid a mortar joint of extra thickness, to have ready a few bricks of extra thickness. The key bricks are sometimes placed with their breadth parallel to the axis of the bridge, but there is no necessity for doing so.

The method of forming the flat arches over doors and windows and similar small openings is shown in Plate XV, and is usually made the height of four courses of bricks; but in considerable buildings, it may be made the height of five courses. It will be seen that all the joints are directed to the point in which the prolongation of the skew backs meet. The bricks should be rubbed to the required shape, but this trouble is not likely to be often taken in India. To key the arch in, it is usual to have a brick, and not the joint between the two bricks, in the centre; and, therefore, the division of the arch must be managed accordingly. Instead of making the arch quite flat, it will generally be better to give it a camber or rise of one or two inches.

Oblique Arches.—In the arches that have been described, the plan is rectangular, the faces of the abutments being perpendicular to the fronts of the bridge, and each course of masonry is laid parallel to the abutments. In a skew or oblique arch, it is not possible to lay the courses parallel to the abutments, for, were this done, the thrust being at right angles to the direction of the courses, there would be a great portion of the arch on each side, that would have nothing to keep it from falling. In order to bring the thrust into this direction, the courses must be laid as nearly as possible at right angles to the fronts of the arch, and at an angle with the abutment, and this it is which produces the peculiarity of the skew arch. When such arches are built of stone, much nicety is required in shaping the voussoirs, but with brick, (the material always employed in India) they may be built with nearly as much facility as the ordinary arches.

The centrings are made in the usual way, but the courses of bricks are arranged spirally, otherwise, rectangular bricks would not fit. Having built the centring and moulded the top of it with mud and sand as usual, provide a plank as long as the circumference of the arch, about nine inches wide and very thin and flexible. Lay this plank flat on the centring mould making its surface touch everywhere, and bringing one corner to the corner of the abutment, and the middle of the same edge to the top of the mould. The long edges of the plank will indicate the spiral lines, and the short ends at right angles will show the form of the toothings to be built on the edge of the abutments of *rubbed* bricks. By moving the plank equal spaces, and ruling along its edge, parallel spiral lines may be drawn on the mould, at half brick width, which will show the workmen the bonding of every course. The bricks in oblique arches radiate as in direct arches and are set at right angles to the curve in the same way.

The connection between the top of the abutment and the bottom courses of the arch, require peculiar care in the segmental skew, and rampant* arches. In the first, the thrust of the arch being very great, it will be well in heavy arches to make the joints of the inferior courses of the abutment, for some courses at least below the impost, oblique to the horizon to counteract any danger from *sliding*. The top stone of the abutment, termed the skew back, or impost of the arch, should be well bonded with the stones of the backing, and it should be thick enough to resist the pressure on it without chance of breaking.

In the skew arch, the abutments are not uniformly loaded, and their thickness should, therefore, be suitably regulated; the thrust too being less regular than in a common arch, it is still more important that in such arches the centrings be taken down before the mortar is set, so that inequalities of pressure may be distributed among all the mortar joints and subsequent cracks be avoided.

In rampant arches, the impost joint being oblique to the horizon, care must be taken, if this obliquity be not less than the angle of friction of the stone used, either to cut the impost into steps, or else to use some suitable bond or iron cramps and bolts to prevent disjunction between the arch and abutment.

Brick on edge-floors.—In the first place the ground should be truly levelled, (or if the floor is intended to have a slope, the surface must be made parallel to it,) and thoroughly consolidated by being well rammed. On the surface so prepared, which should be about 1 foot 3 inches below the intended level of the floor, a layer of dry sand 3 inches deep must be spread, as a preventive against damp and white ants; on this, two courses of bricks are laid flat, and the upper course set in mortar as in foundations: this will leave about 6 inches for the uppermost, or brick-on-edge-course. The best shaped and burnt bricks should be picked for this course; their surfaces which are to be placed in contact should be rubbed smooth so that they may be laid quite close to each other, with merely a thin joint of fine mortar between them; care should be taken that the workman covers the side of the brick last placed with mortar before he places the next one against it. When finished, the joints should be carefully filled in with a little chunam and water.

The above description of floor is recommended for store-rooms and all godowns on which heavy weights are likely to be placed, but for cutcherries, jails, hospitals, &c., square brick paving is considered preferable.

Square brick floors.—Paving bricks are manufactured at Madras 6", 8", 10" and 12" square and 2" or 2½" thick, and are laid on the same foundation as the bricks-on-edge, but when the floor is not required to be very solid, one of the courses of brick is omitted. They should be correctly squared, and their edges trimmed, that they may be laid with precision, and their joints made as fine as possible, and afterwards neatly pointed with the strongest cement and jaggery water, and rubbed smooth with the trowel. The smaller sizes are

* In a rampant arch the axis is oblique to the horizon.

used for inside floors, and the larger sizes for outside work, such as steps, &c.

Brick-jelly floors.—The bricks are broken to small pieces so as to be able to pass through a one-inch ring, and mixed with a certain proportion of dry lime; when this has been thoroughly mixed, water is added, and the whole raked up and turned over by men with mamooties: this is spread about 6" thick on the courses of bricks laid immediately over the sand, as with the other kinds of floor. The surface is then carefully levelled with long straight edges, and the whole is well beaten by light wooden hand-mallets, shaped like choppers, (*kutthee*) and with the edges of trowels, till the whole mass is reduced to two-thirds of its original thickness. This process of beating will bring a large proportion of lime and the other finer particles of the mortar to the surface, which, when the beating has been carried far enough, may then be rubbed smooth, with small wooden hand floats (*manaaskuttai*) and polished with a trowel, using for this purpose a good deal of pressure. The greatest care must be taken to allow no part of the work to dry from its commencement till it is finished, especial care being taken at the joining of different day's work to blend them so thoroughly that the lines of juncture shall not be discoverable.

Brick-jelly floors have seldom been found to answer well; the surface is very liable to be broken, and when it is once broken up, no partial repairs which can afterwards be made to it, are ever effectual.

SECTION 3.—Asphalte.

Asphalte, or rather asphaltic cement, makes an excellent floor, and is also used for pavements, roofs, covering walls and arches, lining tanks and drains, and covering the ground course of brick work, &c., to prevent the rising of damp in walls. The best is that in which limestone is found impregnated naturally with bitumen, and is in England called Seyssel Asphalte, from the place where that which was first imported into England was quarried.

Asphalte floor.—Break the asphalte in small pieces of about the size of brick-jelly for floors; put some mineral tar (about 1½lbs. to 3½lbs. according to the quality of the mastic required to every 112lbs. of asphalte) into an iron boiler, or common picottah iron bucket, and place on a brisk fire; throw in the asphalte pieces and melt together, taking care to stir it well the while. When fit for use, the mastic will emit jets of light smoke, and freely drop from the stirrer. The boiler should be placed close to the work, but where this is not possible, the mastic must be conveyed in small iron buckets, which, previous to being filled, should be heated for the purpose of preserving the mastic longer in a state of fusion. Should it be wished to convert fine mastic into coarse, add some river sand well sifted beforehand (clean and free from dust), in proportion of about 1 part of sand in weight to 4 parts of asphalte.

The mastic is of two qualities, fine and coarse. The former consisting of asphalte and two only, is used for covering of roofs and

arches, lining of tanks, or as a cement. The latter having certain proportions of sand added to it, is used for pavement and flooring. The coarse mastic is distinguished by a red wash on the outside, but the quality of the two is easily detected, the coarse upon being fractured exhibiting the grit or sand.

The principal points to be attended to in all works in asphaltic mastic are, that the foundations should be solid; that the mastic should be applied very hot; and that the joints should be made perfectly to adhere to one another, that the concrete or brick-work underneath should be dry before the application of the mastic. If the concrete is not dry; the great heat at which the mastic is obliged to be poured upon it will convert the moisture into vapour, which ascending through the fluid mastic will cause it when set to be filled with innumerable air holes. When such air holes are discovered (and they should be carefully looked for) in the progress of the work, the places where they appear must be well rubbed over for the purpose of closing them.

Having selected two guages or moulds (pieces of wood finely planed and of suitable length) of the thickness of the intended floor and about 2 inches wide, and after smearing them well with gingeely oil, place one, close to the wall or one side of the surface to be covered, and at a distance not greater than 2 feet 6 inches, and parallel to it place the other, which will then form the width of the several layers of the floor. In this space the mastic, which should be quickly conveyed from the boiler, is to be spread with a trowel, frequently dipped in gingeely oil. To facilitate this work, a floating rule may be used, also well smeared with the oil, in a sawing direction over the mastic, which will level it to the thickness of the guages or moulds, and any unevenness in the surface may easily be removed by the trowel. When one layer of the floor is finished, a space of equal size is left, which is to be covered at a later period.* Adjoining this vacant space, the two guages are then again to be laid down at the same distance apart as before mentioned, and should be kept down by a brick or other weight bearing upon their outer edges, that there may be no irregularity in the thickness of the mastic. The space between the guages must then be covered with asphalte and rubbed smooth in the manner before described, and when it becomes quite firm and cold, the guages should be carefully removed. The layers of asphalte, on both sides of the space remaining to be covered, render guages unnecessary.

The narrow joints left at both ends by the moulds must be filled in with hot mastic, pressed in and smoothed over with a hot soldering iron.

Two important points to be attended to for the purpose of making the joints of the several layers perfect, are first, that the dust should be cleaned from the edges of the layers; and, secondly, that the asphalte should be poured and worked with much force *close* against them.

* The object of leaving alternate vacant spaces, is that the workman may not have occasion to stand or sit upon any part of the mastic until quite cool.

Section 4.—Scaffolding.

Scaffolding, &c.—A low wall can be built for less money than a high one, because in the former, the materials are easily conveyed to it; no scaffolding is necessary for carrying on the work, and there is none of that loss of time and labor constantly attendant on raising materials to a great height. Whenever the height becomes such that the workman cannot reach his work, (and which should always be beneath his chin,) scaffolding becomes necessary, and this is usually constructed by fixing long poles, which are called *standards*, in upright positions about eight feet apart and four to six feet in front of the wall to be erected; these are crossed and braced together by horizontal poles, called *ledgers*, tied on to the upright ones wherever a stage may be necessary, and shorter poles called *putlocks*, are placed at four or five feet asunder, according to the length and strength of the scaffold boards, one end resting upon the horizontal poles or ledgers, and the other on the wall, over the middle of a stretcher, and occupying the place of a header, which is filled in when the scaffold is struck. The putlocks are finally covered with boards or with palmyras. On the floor of the scaffold thus formed, the bricklayer stands, and the materials, such as bricks, mortar and other portable articles are carried up ladders by labourers from the ground below, in wicker baskets; or occasionally in this country, for the construction of terrace roofs, upon inclined planes formed with palmyra or other poles. An excellent light ladder may be made of two straight stout bamboos for side pieces, with pieces of strong jungle sticks let into mortices cut in them for *rungs*. These pieces may be made much broader than the mortices so as to give the workmen a good foot hold. Heavy stones, pieces of timber, &c., which cannot be carried up a ladder by a single man are raised by blocks and a fall attached above to a strong projecting pole, fixed for the purpose near the top of the scaffolding. The mortar is placed on ledged boards of about three feet square, placed at convenient distances along the scaffold, and the bricks are strewn on the scaffold between the mortar boards, leaving a clear way against the wall for the workmen to move along unobstructedly. The workmen then re-commences the operation of bricklaying, beginning at the extreme left of his course, and advancing to the right until he reaches the angle or quoin in that direction, or the place where his fellow-workman on the same side may have begun.

Thus, he goes on with course after course, until the wall is as high as he can conveniently reach from that scaffold, when another ledger is tied to the poles with their upper surface on a level with the highest course of the wall yet laid, another row of putlocks laid, and the boards are removed up to a new level.

The ledgers and most of the putlocks, however, remain to give steadiness to the temporary structure, and so on to the full height of the wall, piecing out the poles by additional lengths as may be required. If a scaffold be very much exposed, and run to a great height, it must be braced. This is done by tying poles diagonally across, on the outside of the standard and ledgers, and it may be further secured by tying the ends of some of the putlocks to the

ledgers; but an *outside scaffold should never be attached* in any way to the building about which it stands.

The mason's scaffold is double, that is, formed with two rows of standards so as to be totally independent of the walls for support, as putlog holes are *inadmissible in masonry*. It would, indeed, be an advantage if *every* scaffold were made with a double row of poles and ledgers, one being on the inside within a few inches of the wall. This would obviate the necessity of resting the putlogs on the walls, and do away with putlog holes; but the inner row of poles would be constantly in the way of the bricklayer, who could not either set the bricks or draw the joints so well as if he were unobstructed.

The scaffolding and implements used in this country are of the simplest kind, and for works of an ordinary nature, there will be no advantage in adopting others of a more expensive, though of a more efficient description. Wicker baskets are used for carrying earth, bricks, mortar, &c.: they soon wear out, but then their cost is very trifling, and they are readily procured in every village. Earthen pots are used for carrying and holding water which is taken out of them, when required by the bricklayers, with a ladle (*aucapai*) formed of a coconnut shell attached to a short stick. Heavy stones are transported to the work in carts; and then lifted and carried with poles and ropes. When a large work is to be undertaken, the execution of which will extend over two or three years, it may often be worth while to make use of machinery and the implements commonly employed in Europe. Thus, mills may be erected for grinding mortar, trucks and wheel-barrows prepared for conveying stones and other materials and tramways laid down for them to run upon. From not being familiar with such things, the natives will at first be awkward in using them, and the amount of work done with their assistance will not be so great as that done in the usual way, but practice will alter this. If, however, the work is *only* to last for a few weeks, it would not be proper to introduce machinery, the use of which would only be learned when there was no longer any occasion for it.

The usual charge for scaffolding is at the rate of 5 per cent. on the total cost of the work.

CHAPTER V.

Roofs.

Architects include, under the term roof, not only the exterior covering of a house, but all the beams and other parts necessary to support that covering.

Arched Roofs.—Arched roofs are required for magazines and other military buildings, but they are rarely put over civil buildings, whether public or private. They cost more than terraced or tiled roofs, and their great weight renders thick, and therefore, expensive walls necessary. Several of the old travellers' bungalows were built with arched roofs, but they have always been very unpopular, and more convenient bungalows with tiled roofs are now built at much less cost. The method of constructing arches has already been described, it will not therefore be necessary to say more on the subject here.

Syrian or Pot cylinder Roofs.—These roofs like the last are arched, but formed with hollow earthenware cylinders, instead of bricks, and are consequently much lighter. The cylinders are made on the potter's wheel, and are about 9 inches in length, from 5 to 6 inches in diameter at the larger end, and from 3 to 3½ at the smaller, the ratio of the two diameters depending on the curve of the roof; they are partially closed at top and bottom. The method of constructing the roof is as follows. After the walls have been raised the required height, a centring must be prepared, similar to those used in bridge building, except that it need not be quite so strong. The top of the centring is moulded with mud and sand in the usual way, and when dry, the arch is commenced with brick and chunam on the two side walls of the room, and raised about 3 feet. The cylinders are then laid side by side in chunam, along the length of the room, with their small ends downwards; the second row is placed in the intervals between every two of the first, the third and following rows are placed in the same way, both sides of the arch rising equally, till the last row, which is of course vertical, forced in on the top, completes the whole. Care must be taken during the construction to press every row well against the centring, and to beat into the interstices as much brick-jelly and chunam as possible, to render the mass compact. Two courses of flat tiles in chunam are afterwards placed over the arch, and the exterior plastered, and the surface well rubbed down. Before the tiles are placed, it will be necessary, in order to have a straight slope from the top of the arch each way, to raise the crown and thicken the haunches with brick and chunam, or with jelly and chunam. The centrings should be allowed to stand until the arch is quite dry, and then the bricks and earth

along the middle of it, that is immediately under and near the crown, should be carefully picked out first; then equal portions on either side simultaneously to a distance of about 3 feet, after which, the whole may be rapidly taken down. At intervals along these roofs, and at each end, arches of brick work, one and a half feet broad and nine inches deep, are turned from wall to wall, as aids and binders to the cylinders, which are built up between them and at the same time. Between a fourth and a third of the length of the roof, may be taken up by these brick arches. The parts of the walls, under the brick arches may be strengthened by pilasters on each side; the rest of the wall need not be more than two bricks thick for ordinary spans. This description of roof is not very common in India, and, on the whole, cannot be recommended. It has been adopted successfully in two or three buildings in Madras, but some recent examples of it have been complete failures, from the water during heavy rains lodging in the cylinders, and keeping the roof damp for weeks after the rain had ceased.

Terraced Roofs.—The terraced roof is very common in India, for buildings of a superior class, both public and private; it renders the rooms underneath cooler than a tiled roof, but its cost is greater. The method of construction is as follows. If the space between the walls *does not exceed 14 feet, joists are laid across 1½ feet apart from centre* to centre, but if greater, the length is generally divided into two or more portions, by large beams of wood, and the joists are laid across, at right angles, connecting them with the end walls and with each other (Pl. XVI, Fig. 1.) Over the joists comes a course of brick on edge in chunam, the bricks being of small size (5″ × 3″ × 1″), and placed diagonally, and upon them the levelling course of bricks and flat tiles is laid, to form slopes to drain off the rain water; and over this a thickness of 3″ of *jelly*,* or brick broken small in chunam, very similar to brick-jelly floor; and after this part of the terrace is perfectly dry either two or three courses of terrace or flat tiles are laid in good mortar; and lastly 3 coats of plastering. The joists are sometimes boarded over, the brick-on-edge is then dispensed with, and the jelly is laid directly on the boards, over which the tiles and plastering come as before. The first method of forming the roof is the better of the two, as the boards are apt to become rotten from damp. After the brick-on-edge and jelly have been placed on the joists, a few days ought to be allowed to elapse before the tiles are laid, and these be wetted before being used. The plastering should be done with great care, and the surface well rubbed down. The slope for the water to run off should be about a quarter of an inch to a foot, and great pains should be taken to lay out this slope with regularity, so that the water may run off every part of the roof with equal readiness. A parapet wall of about 1½ feet in height is built round the edge, with a few openings whence spouts project for carrying off the water, and binding walls, of the same height are built over all the cross walls of the house to keep the ends of the joists firm in their places.

Cracks in terraced roofs are usually repaired with a piece of tarred cloth laid over them, or by pouring a mixture of tar, pitch and dammer

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* See *Brick-jelly floors*, page 85.

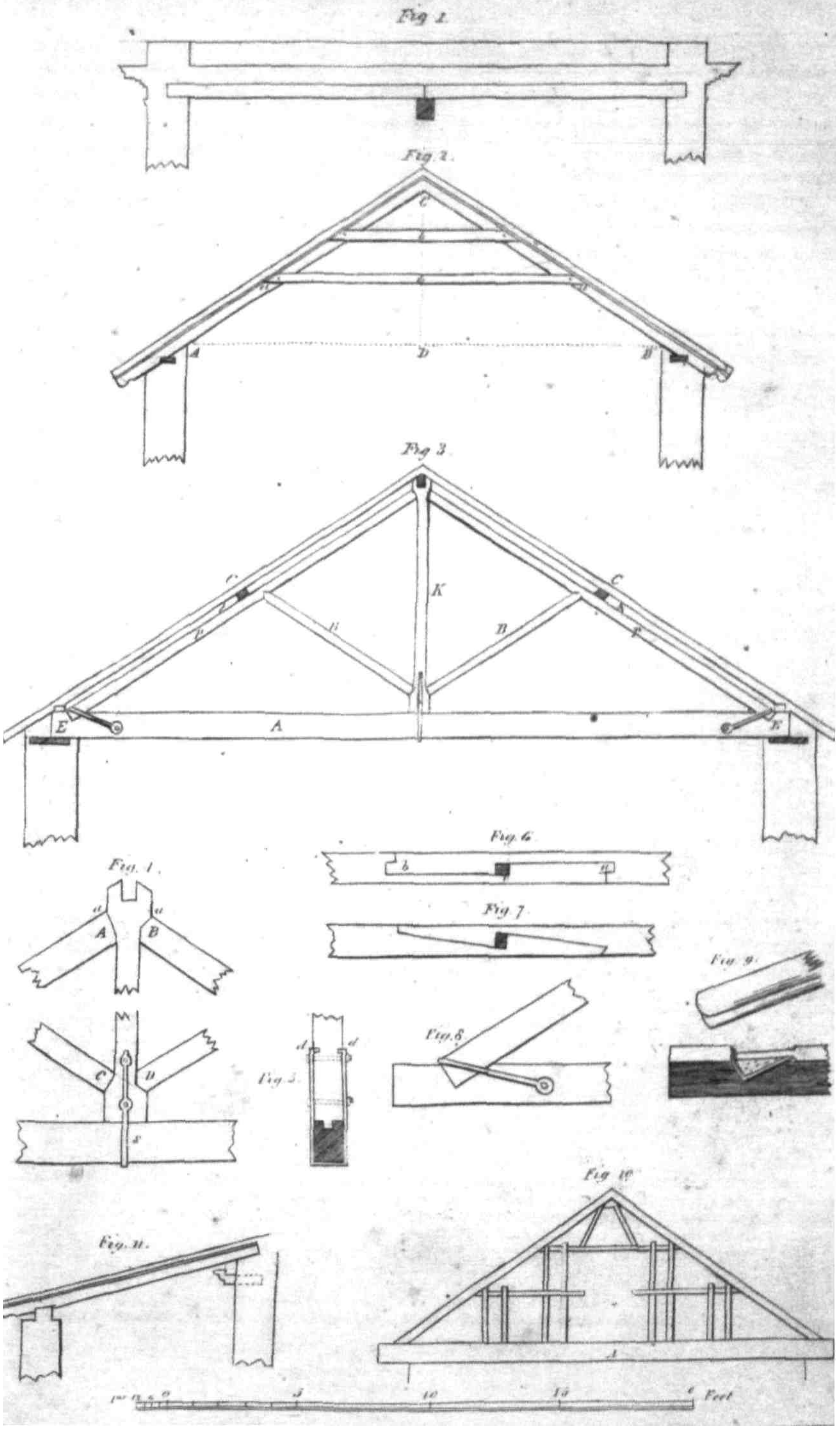
Fig 1.
Fig. 2.
C
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Fig 3
K
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Fig. 4.
A
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C
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Fig. 5.
Fig. 6
Fig. 7
Fig. 8
Fig. 9.
Fig. 10
Fig. 11.
5
10
15
Feet

into them, or by removing some of the plaster from each side, and setting a row of thin bricks or tiles over the crack, either in mortar or in a mixture of tar, brick-dust and lime. If the cracks are slight, these plans will answer, but large cracks in the roofs of old buildings, caused by the bending of the beams, or the subsidence of the walls, cannot be thus stopped. In these cases, it will be better to build on each side of the crack, a wall of one brick-on-edge, plastered and firmly connected with the masonry of the terrace; then a long semi-circular pan tile, made of sheet lead or copper, laid over these two walls, so as to embrace them both standing on the terrace, will prevent the rain falling into the opening. The objection to this plan is that the metal would certainly be stolen; its place may be more cheaply supplied by an arch turned in masonry unconnected with the terrace, but occupying the same place as the metallic plate would, or a row of bricks may be laid flat on the top of the two side walls, but connected by mortar with only one of them, and projecting beyond on each side: a groove should be cut on the under side of the projections, to prevent the rain getting between the top and sides, and the upper surface of the bricks should be plastered with two coats. These roofs often leak from the water lodging in places, owing to the slopes not being regular, or to some of the spouts being choked up with bones or other rubbish conveyed there by squirrels and birds: an examination of the spouts should, therefore, be occasionally made. A leaky terrace being a source of constant annoyance and difficult to repair effectually, great pains should be taken in constructing the roof. The timbers should be seasoned and of sufficient scantling; indeed an excess of depth in the girders to the extent of one or two inches is advisable, and those formed of several short pieces, keyed together, should never be used.

Beams and Joists.—With regard to the scantling of the timbers, for terraced roofs, a common rule is to give the joists half an inch of depth and a quarter of an inch of breadth, for every foot of length; and the beams or girders, three quarters of an inch of depth, and half an inch of breadth, for every foot of length. This rule is safe and sufficiently correct, but not altogether so; for, the strength of timbers of rectangular section exposed to transverse strain is: 1, Directly proportional to the breadth. (A piece twice as broad is twice as strong). 2, Proportional to the square of the depth. (A piece twice as deep is four times as strong; thrice, nine times, &c.) 3, Inversely proportional to the length. (A piece twice as long has only half the strength, &c.) Hence depth is of much greater importance than breadth, as a small increase of the former adds greatly to the strength of the beam, while a similar small addition to the latter is comparatively unimportant. A piece of timber, therefore, will never be laid on its broad side when strength is required, but when beams, used to span a large opening, have a breadth very small in comparison with their depth, it will be a necessary precaution to retain them by some means in that position, in which the greatest transverse dimension is truly in the vertical line, or in the position of depth, as it would be greatly weakened by any turning of the beam in the middle of its length, tending to throw it out of that position.

When a long beam is laid over several points of support, the

strength of the intermediate parts is nearly doubled, or twice as much as when the beams are cut into short lengths. Hence the importance of using joists, purlins, and rafters in considerable lengths, so that a joist may extend over several girders, purlins over several trusses, and a rafter over several purlins; also, by contriving so that the joinings shall not be opposite one another, a floor or roof may be made tolerably equal in strength.

Joists need not exceed three inches in thickness and they should never be made less than two inches. In a terraced room, in the Government Office in the Fort, 21 feet in breadth, there are no girders —the joists are 11 × 3 inches scantling and are placed one foot nine inches apart from centre to centre. In another room, $20\frac{3}{4}$ feet broad, in the same building, the joists are 11 × 3; and in a third, $16\frac{1}{2}$ feet broad, the joists are 8 × 3 inches scantling. This way of forming the roof is not common in Madras. When the breadth of the room does not exceed 20 feet, there will not be much difficulty in procuring girders of the requisite length and scantling. The breadth does not often exceed 24 feet, but there is a room, 28 feet in breadth, in the Madras Club-house with girders 21 × 15 inches scantling. A terraced room in the Medical School $25\frac{1}{2}$ feet in breadth has girders 22 × 15 inches scantling. The dimensions of girders must sometimes depend on the dimensions of the timber that can be procured for them—when depth is diminished, the breadth must be increased and *vice versâ*. The girders should not be placed more than 10 feet apart, but the precise distance will depend on the length of the room and the position of the doors and windows. Girders of great length may be formed of three or four pieces, each about 3 inches in thickness, held together with iron hoops, or bolted together, with a little space between the pieces. When made in this way, sound timbers may be selected for the pieces, but the centre of large solid beams cannot be examined, and it is often in a state of decay. All beams, joists, &c., ought to be cut to a camber, or roundness, that is, with an angle in the centre of their lengths, so that their middles shall raise above the levels of their ends, and the convexity may be about one inch in eighteen or twenty feet. The reason is that all timber, partly from its own weight, but principally from the weight of the covering or burden it has to bear, will bend down, or as workmen term it, *sag*. The girders should rest on wooden wall plates or granite stones about four feet in length, and from six to nine inches in depth; so that the pressure may be distributed over a greater extent of wall, and the ends moreover should not be built into the wall, but an open space of about an inch should be left on each side, and also at top, by placing a flat stone above, to carry the wall. Girders should be laid from a foot to a foot and a quarter into the wall, and joists six to nine inches.

The Sloping Terrace.—This description of roof, which is known also as the Bengal roof, from requiring but little slope, is well adapted for verandahs, but it is not often put over the principal rooms of a building. When the latter are arched or terraced, verandahs having this roof harmonize better with them, than those covered with pan tiles. The rafters should be placed one and a half foot apart from centre to centre, and the reepers or laths, which are nailed to their

upper surface at right angles, should be half an inch thick and two inches wide and placed *six inches* apart from centre to centre, so that the flat tiles (which are usually six inches in length) may have an inch at each end supported. The covering usually consists of three courses of tiles, of which the first is laid on the reepers, with mortar between the joints, the second and third courses are set in mortar, and are covered with three coats of plastering. The tiles should be dipped in water before being used, so that the mortar may adhere firmly to them, and the plastering should be done with great care, and well rubbed down. Sometimes there are only two courses of tiles, and sometimes a thickness of one and a half inches of *jelly* in chunam (the pieces of brick being broken very small) is interposed between the second and third courses of tiles.

Cracks in these roofs are repaired in the same way as those in terraces, that is, by pouring tar and pitch into them. Cracks are usually caused by the sinking, or *sagging*, of the rafters, which must of course be followed by the disunion of the tiles, and as the cracks are difficult to repair effectually, care should be taken to use none but seasoned wood of sufficient scantling. When the breadth of the verandah is eight or nine feet (and it is not advisable to make sloping terraced verandahs wider), the upper side of the roof should be two feet higher than the lower: this slope will be quite sufficient for the water to run off readily.

Rafters.—When the verandah is 6 feet wide, the rafters should be 2″ × 3½″ scantling; when 8 feet wide, 2″ × 4″; and when 10 feet wide, 3″ × 5″. When the verandah pillars are 6 feet apart, the breast summers (or beams on which the lower ends of the rafters rest) should be 3″ × 5″ scantling; when 8 feet apart, 4″ × 6″; and when 10 feet apart, 5″ × 7½″. When a verandah is to be added to a finished building, holes must be made in the wall to receive the ends of the rafters, or more commonly, holes are made six or eight feet apart to receive brackets (Pl. XVI, Fig. 11), supporting pieces of timber on which the ends of the rafters rest. The rafters should, however, enter the wall, a few inches, and the tiles next the wall should be partly within it, otherwise the rain will get in at the junction of the roof with the wall.

Couple roofs with flat and pan tiles.—The most simple form of a roof is that which has only one row of timbers, arranged in an inclined plane, which throws the rain entirely to one side. This is called a *shed roof*, or *a lean to*. For rectangular buildings, the roof consists either of two rectangular planes of equal breadth equally inclined, and terminating in a line parallel to the horizon, when it is called a *pent roof*, or else the four sides of the roof are formed by inclined planes, when it is said to be a *hipped roof*, and the inclined ridges, springing from the angles of the wall, are called the *hips*. If two portions of roof meet and intersect each other at right angles, a hollow or concave angle will be produced, and that is called a *valley*.

The covering consists either of flat and pan tiles, or only of the latter. The additional expense of the flat tiles is inconsiderable; they give the interior of the rooms a more finished appearance, and

keep out the vermin which are sheltered in the spaces between the pan tiles. Sometimes a bamboo mat is substituted for the flat tiles, and sometimes bamboos are used as reepers and tied with string instead of being nailed to the rafters, but, mats and bamboos are perishable, and these paltry expedients should not be adopted, except in the roofs of temporary structures. When both flat and pan tiles are used, the former, which consist of a single course, are laid on the reepers, with mortar between the joints. The pan tiles are then laid over them in rows touching each other from top to bottom. The pan tiles are made somewhat smaller at one end than the other, with a view to their overlapping each other, which they should do to the extent of not less than one-fourth of their length, and the overlap should be uniform throughout. A second course of pan tiles is then laid with their convex sides upward and overlapping each other: these tiles are placed so as to cover the intervals between the rows in the first course. The ridges and hips are covered with tiles of a larger description, also overlapping each other, and they are generally set in mortar. The ridge and hips are usually plastered, and the sides also, in stripes six or nine inches wide, with intervals of one and a half or two feet between them. These stripes go by the name of *chunam borders*, and their object is to bind the tiles together. When there is no verandah *to the building, it is a common practise to fix the ends of the rafters* in the walls, and finish the edge of the roof in a small cornice, and the consequence is that the water from the roof runs down the side of the wall, to its great disfigurement, and also to its detriment, if the bricks are set in mud, which they usually are in private houses. It will be much better to fasten the rafters to a wall plate and allow the eaves to project a foot or more as in Fig. 2, (Pl. XVI.)

The slope of a pan tiled roof should be one-third the span, that is, C D (Pl. XVI, Fig. 2) should be one-third of A B. The lower part of a pan tiled roof is often made with a less slope than the upper, but the practise is a very bad one; the slope should be in a straight line from the top to the bottom.

When these roofs begin to leak, the tiles in the intervals between the chunam stripes are taken up and re-arranged, and this is called "shifting tiles," or else the whole of the tiles are taken off and re-arranged, and this is called "shifting tiles and new chunam borders." The consequence of repairing the roofs in this way is generally that the leaks become larger and more numerous, and the reason is that leaks are in most cases owing to the channel tiles, or those placed with their concave side upwards being broken, and in the course of shifting the tiles, a great many more become broken. It will be a better plan to note carefully where the leak is, and then send a man on to the roof who, treading only on the chunam stripes, should examine the spot where the leak is, and should he find one of the channel tiles broken, he can replace it with a whole one, and the leak will probably be effectually stopped and at scarcely any expense. When the roofs are very much out of repair, the estimate must be for "shifting tiles and new chunam borders, with a fourth new pan tiles, and a fifth new flat tiles," or whatever proportion of new materials may be found necessary, and at the same time, any parts of the wood work that are found decayed, must be renewed.

If these roofs are well constructed, with good tiles, they will be found quite water-proof, without having recourse to a double course of pan tiles, which is the practise on the Western coast. A cheap and easily applied glaze for tiles is, however, a desideratum, for though the tiles can be made so as to prevent any water dropping through, yet after being exposed to constant heavy rain, for several weeks together, they become so completely saturated with water as to be injurious to the wood work on which they rest. It is said that dipping the channel tiles in a strong solution of jaggery in white-wash, prevents their afterwards absorbing water. The experiment deserves a trial, as it involves very little additional expense.

Tiled roofs are more common than any other kind, as they are durable and are easily and cheaply constructed in most situations, but large public buildings, such as barracks and hospitals, are now generally terraced. There can be no doubt that the old barracks, which were tiled, were excessively hot; but this does not seem to have been due so much to the nature of the roof as to the lowness of the walls.

Couples.—The usual frame work of tiled roofs consists of a series of couples, each formed of two rafters *a a* (Pl. XVI, Fig. 2) meeting at an angle and connected by one or two pieces of wood *b b* termed *collar beams*. The couples are generally made with palmyras, but sometimes with teak or a commoner description of wood. The couples are placed one and a half foot apart from centre to centre and in hipped roofs (in order that the slopes to the four sides may be uniform), the distance of the extreme couples from the ends must be equal to half the breadth of the room. The rafters from the corners to the extremity of the ridge or highest part of the roof are called *hip rafters*, and the shorter ones which meet the hips, *jack rafters*. The upper extremity of the hip rafters rests on a piece of wood, nailed to the side of the extreme couples near the top; it is also fastened by large nails. Nails are used to fasten the rafters together and also for attaching the collar beams to them, and the jack rafters to the hip rafters. The reepers should be always of teak, as they cost but little more than those of palmyra, while they present a better appearance and last longer. The reepers should be two inches wide, six inches apart from centre to centre, and nailed to every alternate rafter, taking care that no rafter is without its due proportion of nails. There is no ridge pole, but the two upper reepers should be four inches wide and meet at top. If the reepers are made narrow, or placed too far apart, the tiles will be constantly breaking and falling through.

For a span of 12 feet, teak rafters should be $4\frac{1}{2}'' \times 3''$; for a span of 16 feet, $6'' \times 3''$; for a span of 20 feet, $7'' \times 3\frac{1}{2}''$; and for a span of 24 feet $8'' \times 3\frac{1}{2}''$. The collar beams may be from $3'' \times 2''$ to $4'' \times 2\frac{1}{2}$.'' Palmyra couples and reepers should be tarred; they will thus be better preserved against the attacks of white ants. Teak couples should be varnished with wood oil.

Thatched roofs.—The frame work of thatched roofs may consist of a series of couples but they need not be placed so close together as when they are intended to support tiles. It may consist also in a great measure of bamboos which will be as durable as the material

with which they are to be covered. Reeds, jungle grass, straw, and the leaves of the coconut and palmyra are used for thatching. The two first are the best; a thatched roof of jungle grass has a very neat appearance, but to make it entirely water proof, it is advisable to cover it with a layer of straw, kept from blowing off either by ropes of the same material, or a light trellis work of bamboo. The straw will have to be renewed annually, but the thatch underneath will last for many years. Thatched roofs have the advantage of cheapness, and they keep the rooms beneath them cool, but, on the other hand, they are liable to be set on fire, and they harbor vermin of various kinds, and are constantly requiring repair. Except in particular situations they should only be applied to temporary buildings. The slope must be one-half the span, or the sides must be inclined at an angle of 45° with the horizon, and the angle formed by them at the ridge will be a right angle. Thatch, by being dipped in lime wash, is rendered somewhat less combustible.

Trusses.—It is generally thought that a span of 18 feet is the limit for a couple roof, and that for greater spans, *trusses* must be employed. The roof of the Trinity Chapel, at Madras, is, however, an instance to the contrary, for that has a roof formed with palmyra couples, and the span is 26 feet, and there are buildings elsewhere with similar roofs, spanning 24 feet, and it is not often that roofs of greater span are required in India. Walls being rarely made less than a foot and a half in thickness in this country, they are quite strong enough to sustain the outward pressure exerted by the rafters; but, as this is not the case in England, when the span is 20 feet and upwards, the ends of the rafters are tied together, and prevented spreading by a piece of timber, extending from one wall to the other, and called a *tie beam*.

In Plate XVI, Fig. 3, A is the tie beam, to which the feet of the rafters P P are fastened. These rafters are called *principal rafters*, to distinguish them from others which will be described presently. To prevent the tie beam from sinking or *sagging* in the middle, it is suspended to the top of the rafters by the *king post* K; and to prevent the rafters bending, and giving a concave surface to the covering of the roof, they are supported in the middle by oblique *struts* or *braces B B*, from near the bottom of the king post, placed so as to be nearly perpendicular to the direction of the rafters. The feet or bottom of the rafters are let into the tie beam by proper mortices and tenons to be hereafter described; and this letting in does not take place at the extreme ends of such tie beams, but at such distance from them as will prevent the lateral strain of the rafters from pushing away the portion of wood that resists their pressure. The tops of the rafters, it will be seen, do not touch or abut against each other, but are let into *shoulders* cut out of the king post, near its top, in such direction as to be at right angles with the length of the rafters, while the bottom of the king post is morticed into the centre of the tie beam. The struts B B, for supporting the rafters, are inserted, as nearly as may be, under the middle of their lengths, and the lower ends of these struts rest upon shoulders cut out near the bottom of the king post, such shoulders being made at right angles to the direction of the struts. The king post is always made broader than it is deep, in order

to admit of the formation of these shoulders, without becoming too much weakened. It might be formed of a rectangular piece of timber, or one that is flat on all its four sides, but as this would add greatly to the weight of the piece, it is customary to cut king posts into the form drawn in the figure, the back and front of the king post are left flat and parallel, and its thickness is usually the same as the width of the tie beam. A truss, such as has been described is called a *king post truss,* and fulfils every condition of strength and stiffness that can be required in a roof when the span is from 20 to 30 or 35 feet, provided the size of the timbers are well proportioned to each other, and the joints are well and securely made. The tie beam cannot sink in the centre being upheld by the king post; the king post is upheld by the rafters, and they are prevented bending or changing figure by the struts.

When timber cannot be procured of sufficient length in a single piece to form the tie beam, two or more pieces of timber must be united together by their ends, or in the direction of their length, and this operation is called *scarfing* timber, and is performed in various manners. The best scarf against longitudinal extension, as in tie beams, is that shown by Fig. 6, (Pl. XVI), where the upper and under beams are cut or let into each other, in the manner shown in the figure. The under beam has a tongue or *tenon* formed at its extreme end like *a* with a corresponding notch for its reception in the upper beam, and the end of the upper beam is similarly treated in respect to the lower one. To permit these tenons, to pass into the notches provided for them, it is necessary to cut away a portion of the intermediate part of the joint at *c*, and this is afterwards filled up by a piece of hard wood called a *key,* fitting the hole, and driven tightly into it. The thickness of the key ought to be equal to one-third of the entire beam. The addition of bolts and straps makes this an excellent scarf. Fig. 7 represents another form but not so good as the preceding. The joint at the foot of the principal rafters, is shown in Figs. 8 and 9. The mode of fixing the iron stirrups (Fig. 8) to unite the feet of the principal rafters with the tie beam, is very often erroneous; because such straps are frequently fixed at right angles to the rafter, and they become quite loose when the roof settles. The strap is intended to prevent the rafter foot sliding along the tie beam; it should, therefore, be placed as nearly as possible coincident with the direction of the tie beam, or at any rate in a much more sloping form than is generally met with, and, of course, it should be let into a notch on the upper surface of the rafter to prevent its sliding upon it. The stirrup, instead of being nailed to the tie beam, should terminate in loops or eyes, through which and the tie beam a strong screw bolt should be passed, which not only attaches the stirrup more strongly to the beam than nails can do, but permits a motion, by which the tie can adjust itself to any varying strain between the beams, without the danger of its breaking off. The joint at the upper end of the principal rafter differs from that of the lower end in some respects; but the difference is not material in respect to the principle of forming the joint. Making the king post larger at the head, allows a more effectual abutment being obtained; and this abutment should be, in common joints, square to the back of the rafter, as at *A*, (Fig. 4) with a short tenon shown by the dotted lines. When

the head of the post is not sufficiently large to get the abutment square to the back of the rafter, it is usual to cut it as at B. The same remarks will apply to all similar joints; such, for example, are the joints between the braces or struts and king post at C and D. An iron strap is usually spiked on to each side of the head of the king post for more firmly uniting it with the tops of the principal rafters. The best method of attaching the king post to the tie beam is to make a short tenon to the lower end of the former, and to support the beam by means of a strap. In Fig. 4, S is the strap; its hold of the king post may be improved by turning the ends as at *d d* in the section (Fig. 5); these, when well fitted, will, with the addition of bolts, give the strap a firm hold. The strap may be formed out of a bar of flat iron, about three inches wide, and half an inch thick.

Thin plates of iron decay very rapidly, particularly in damp situations; therefore they should be well secured from rust by being painted as soon as they are made. When iron once gets rust, so as to form a scale, whatever coat of paint or varnish is put over this, the rust will go on progressively under the paint. To prevent iron rusting, it should be heated and dipped in raw linseed oil or rubbed over while hot with wax.*

Trusses are not placed so close together as couples, for that would render roofs too heavy, expensive and unnecessarily strong. They are usually placed eight or ten feet apart, and the actual roof is built upon them by means of what are called *purlins*, being long pieces of square timber, placed in horizontal directions, at equal distances apart, along the upper surfaces of the principal rafters, as shown at C C in Fig. 3, (Pl. XVI), which exhibits only a transverse section or end view of them. When joints are necessary in a purlin, they must always take place upon a principal rafter. The purlins project considerably above the principal rafters, because these timbers are merely notched on to each other, to prevent their slipping, being let about half an inch into the principal rafters, while the rafters are let about as much into them before they are nailed.

The purlins being fixed, the *common rafters* succeed, and these rest upon the purlins in their middle parts as at C C, while their upper ends are nailed together and rest on the top of the *ridge piece*, that is let into notches cut to receive it in the tops or crowns of all the king posts. The lower ends of the common rafters are notched and nailed to the top of a plate or piece of a timber called a *pole plate*, which, like the purlin, runs the whole length of the building, and is supported on the ends of the tie beams, as at E E (Fig. 3), or upon the tie beams and wall between them conjointly; or wholly upon the walls when the tie beams are not long enough to carry them. Reepers are nailed at right angles, to the upper surface of the small rafters to receive the tiles. A truss of the above kind put up some years ago at Madras, and spanning 20 feet, is formed of timbers of the following dimensions—Tie beam, 7″ × 4″; principal rafters, 4″ × 5″; king post, 4″ × 5″; struts, 3″ × 5″; purlins, 3″ × 5″; rafters, 3″ × 4″.

* The iron bars to windows should always be treated in this way, or the ends will become encrusted with rust and split the frames in which they are inserted.

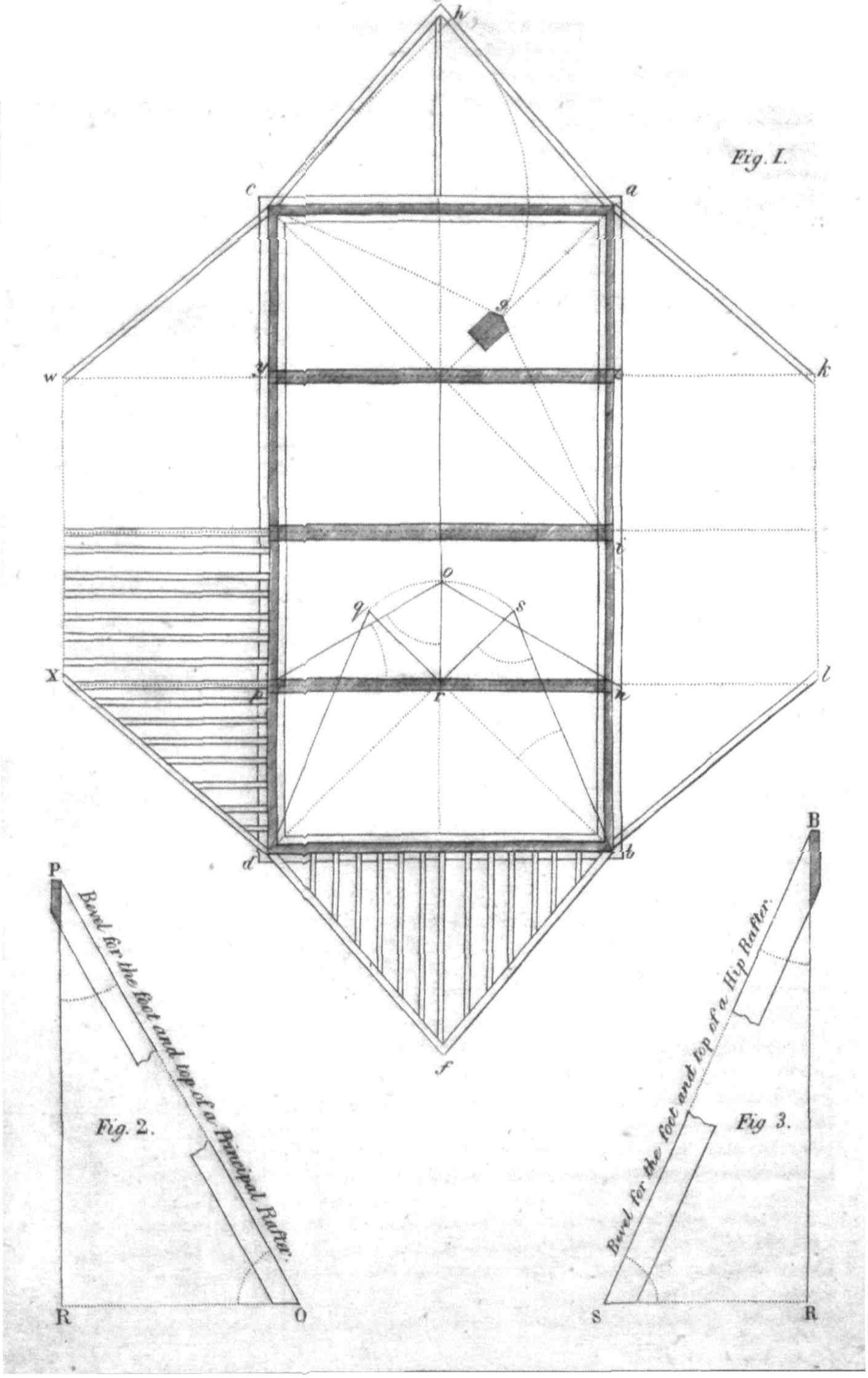
Fig. I.
e
h
c
a
g
w
y
k
i
o
q
s
X
p
r
n
l
d
b
f
P
Bevel for the foot and top of a Principal Rafter.
Fig. 2.
R
O
B
Bevel for the foot and top of a Hip Rafter.
Fig 3.
S
R

When the span is more than 30 feet, the tie beam is supported, at additional points, by suspension pieces called *queen posts*, from the bottom of which spring additional struts. The roof of the European hospital at Arcot, of 40 feet span, is supported on queen post trusses. The scantlings of the timbers are as follows—Tie beam, 13″ × 10″; principal rafters, 11″ × 8″; king post, 9″ × 8″; queen posts, 8″ × 8″; braces, 8″ × 8″ and 7″ × 7″ wall plates, 7″ × 7″; straining pieces, 8″ × 7″; purlins, 7″ × 5″.

Fig. 10 (Pl. XVI) represents what is called the *Malabar truss*, which is very common in native buildings, but it is in reality not a truss at all. A is no longer a tie beam, and subject only to longitudinal extension, but it bears the weight of the roof, and acting the part of a girder, it has to be made of considerable scantling. The construction has nothing to recommend it.

Plate B represents how to lay out a roof so as to find the lengths and bevels of every particular part, and consequently the quantity of the whole in the construction of a Hip Roof.

Let *a b c d*, (Fig. 1, Plate B) be the plan of a rectangular hipped roof; and, in order that the slopes on the four sides may be uniform, the distance of the extreme trusses, from the ends of a room, must be equal to half its breadth, let *z y* and *n p* be therefore the position of the extreme trusses; and let *r b*, *r d*, also *e m* and *a m*, be the base of the four hips, and *o*, *r*, be the height of the pitch. From *o*, the height of the pitch, draw the lines *o n* and *o p* which are then the lengths of all the *principal* or *common rafters*. On the point *r* erect the perpendiculars *r s* and *r q* each equal to *r o*, the height of the pitch, and draw the lines *s b* and *q d* which are then the lengths of the *hip rafters*. At the ends, *a c* and *b d* describe the triangles *b e d* and *a f c* whose sides *b e*, *d e* and *a f*, *f c* are each equal to *s b* the length of the hip rafter. Continue the central lines of the trusses *z y* and *n p* to *l* and *x*, and to *k* and *w*, making *k z*, *l m*, *y w* and *p x* each equal to the length of a principal rafter, and draw the lines *a k*, *k l* and *l b*, also *c w*, *w x* and *x d*. This being done, draw in all the other principal rafters as are requisite at proper distances, and lastly, between the principal rafter draw in all the small or *jack rafters* and then the lengths and angles of every particular part of the whole roof will be determined, and from which a just estimate of the quantity timber that will be required may be made.

In Fig. 2, (Pl. B), the angle O P R being equal to the angle *o p r* in Fig. 1, therefore the angle at P is the bevel of the feet of all the principal rafters as the angle at O, for the same reason, is the bevel of their tops; and the angle S B R, Fig. 3, being equal to the angle *s b r* in Fig. 1, therefore the angle at B is the bevel of the foot of the hip rafters and S the bevel of the tops.

There are two angles to be formed to fit a jack rafter to the upright side of a hip rafter; that is, the one on *its upper surface*, and the other on *its sides*. The angle on its upper surface, is the angle made by the upper edges of the hip and jack rafters, or that angle which every jack rafter makes with the hip rafter, as every one of the

angles between *e* and *d*, and the angle on its sides is the bevel at O Fig. 3, (Pl. B), that is, the top of the common rafters is the side bevel of the jack rafter. As jack rafters are parallel to one another, therefore all these angles against the hips are the same.

To find the hip angle, or what is generally termed "*the backing of the hip*," let fall a perpendicular from the point *c*, as *c h*, on the hip *f a*, make *c g* equal to *c h*, also make *a i* equal to *a c*, draw the lines *c g* and *g i*; and the angle *c g i* will be the angle or back of the hip.

TABLES OF SCANTLINGS OF GIRDERS, &c.

The following tables, from Tredgold's Carpentry, will be fonnd useful; but the scantlings cannot be implicitly adopted, as they are intended for a different kind of wood from that used in this country and for different floor and roof coverings.

Table of the Scantlings of Girders of Yellow Fir, for different bearing, from 10 *to* 36 *feet; Girders* 10 *feet apart from middle to middle. The bearing is the distance between the centres of the supporting wall plates; and the scantlings the least that will answer the purpose.*

Length of bearing in feet.	Depth 10 inches.	Depth 11 inches.	Depth 12 inches.	Depth 13 inches.	Depth 14 inches.	Depth 15 inches.	Depth 16 inches.	Depth 17 inches.	Depth 18 inches.	Length of bearing in feet.
	Breadth in ins.	Breadth in ins.	Breadth in ins.	Breadth in ins.	Breadth in ins.	Breadth in ins.	Breadth in ins.	Breadth in ins.	Breadth in ins.	
10	7½	5½	4	3½	2¾	2¼	1¾	1½	1¼	10
11	9	6¾	5	4¼	2¼	2¾	2¼	2	1¾	11
12	10½	8	5¾	5	3¾	3¼	2¾	2¼	2	12
13	12½	9½	6¾	5¾	4½	3¾	3	2½	2¼	13
14	14½	10¾	7¾	6¾	5¼	4½	3½	3	2½	14
15	16½	12½	9	7¾	6	5	4	3½	3	15
16	18¾	14	10¼	8¾	7	5¾	4¾	4	3¼	16
17		16	11½	9¾	8	6¼	5¼	4½	3¾	17
18	...	17¾	13	11	8¾	7¼	6	5	4	18
19	...	19¾	14½	12	9¾	8	6½	5½	4¾	19
20	...		16	13½	10¾	9	7¼	6	5¼	20
21	...	...	17½	15	12	9¾	8	6¾	5¾	21
22	...	...	19½	16½	13	10¾	8¾	7½	6¼	22
23	...	...		18	14¼	11½	9½	8	6¾	23
24	...	...	...	19½	15½	12¾	10½	8¾	7½	24
25					16¾	13¾	11¼	9½	8	25
26	Depth 19 ins.	Depth 20 ins.	Depth 21 ins.	...	18¼	15	12¼	10¼	8½	26
27				...	19¾	16	13	11	9¼	27
28	Breadth in ins.	Breadth in ins.	Breadth in ins.	...		17¼	14¼	11¾	10	28
29				...	...	18½	15¼	12¾	10¾	29
30	9¾	8½	7¼	...	...	19¾	16¼	13½	11½	30
31	10¼	9	7¾	...	...		17¼	14½	12¼	31
32	11	9½	8¼	...	...	...	18½	15½	13	32
33	11¾	10	8¾	...	...	...	19¾	16½	14	33
34	12½	10¾	9½	...	...	...		17½	14¾	34
35	13¼	11½	10	...	...	...	...	18½	15¾	35
36	14	12	10½	...	...	...	...	19½	16½	36

Table of Scantlings for Single Joisting, or Bridging Joists, of Yellow Fir, for different bearings, from 5 to 25 feet; the distance from middle to middle 12 inches.

Length of bearing in feet.	Breadth 1¼ inches.	Breadth 1½ inches.	Breadth 2 inches.	Breadth 2¼ inches.	Breadth 2½ inches.	Breadth 2¾ inches.	Breadth 3 inches.	Breadth 3¼ inches.	Breadth 3½ inches.	Breadth 4 inches.	Length of bearing in feet.
	Depth in ns.	Depth in ins.	Depth in ins.	Depth in ins.	Depth in ins.	Depth in ins.	Depth in ins.	Depth in ins.	Depth in ins.	Depth in ins.	
5	5¾	5½	5¼	5	4¾	4½	4⅜	4¼	4⅛	4	5
6	6¼	6	5¾	5½	5⅜	5¼	5	4⅞	4¾	4½	6
7	7	6¾	6½	6¼	6	5¾	5½	5¾	5¼	5	7
8	7¾	7½	7	6¾	6½	6¾	6¼	6	5⅞	5¾	8
9	8½	7⅞	7½	7	6⅞	5¾	6½	6¼	6	5⅞	9
10	9	8½	8	7¾	7½	7¼	7	6⅞	6¾	6½	10
11	9½	9	8¾	8½	8	7¾	7½	7¼	7	6¾	11
12	10	9¾	9½	9	8½	8¼	8	7¾	7½	7¼	12
13	10¾	10¼	9¾	9½	9	8¾	8½	8¼	8	7¾	13
14	11	10½	10	9¾	9½	9¼	9	8¾	8½	8	14
15	11½	11	10½	10	9¾	9½	9¼	9	8¾	8½	15
16	12¼	11½	11	10¾	10½	10	9¾	9½	9¼	8⅞	16
17	12¾	12	11½	11¼	10¾	10½	10¼	10	9¾	9¼	17
18	13¼	12½	12	11½	11¼	10¾	10½	10¼	10	9½	18
19	13¾	13	12½	12	11½	11¼	10¾	10½	10¼	10	19
20	14¼	13½	13	12½	12	11½	11¼	11	10¾	10½	20
21	14¾	14	13½	12¾	12½	12	11¾	11½	11	10¾	21
22	15	14½	13¾	13¼	12¾	12½	12	11¾	11½	11	22
23	15½	14¾	14	13½	13	12¾	12¼	12	11¾	11¼	23
24	16	15¼	14½	14	13½	13¼	12¾	12½	12	11¾	24
25	16½	15½	15	14½	14	13½	13	12¾	12½	12	25

Table of Scantlings of timbers of different spans, from 20 to 30 feet, for the roof shown in Figure 3, Plate XVI. The trusses supposed to be not more than 10 feet apart, the pitch of the roof about 27°, the covering slate, and the timber Yellow Fir.

Span.	Tie beam.	King Post.	Principal Rafters.	Braces.	Purlins.	Small Rafters.
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
20	9½×4	4×3	4×4	3½×2	8 ×4¾	3½×2
22	9½ „ 5	5 „ 3	5 „ 3	3¾ „ 2¼	8¼ „ 5	3¾ „ 2
24	10½ „ 5	5 „ 3½	5 „ 3½	4 „ 2½	8½ „ 5	4 „ 2
26	11½ „ 5	5 „ 4	5 „ 4¼	4¼ „ 2½	8½ „ 5	4¼ „ 2
28	11½ „ 6	6 „ 4	6 „ 3½	4½ „ 2¾	8¾ „ 5¼	4½ „ 2
30	12½ „ 6	6 „ 4½	6 „ 4	4¾ „ 3	9 „ 5½	4¾ „ 2

CHAPTER VI.

BRIDGES.

Definitions.—The portions of the roadway, at each extremity of the bridge, which lead to it, are termed the *approaches*. The extreme supports of a bridge, by which it joins upon the banks of a river, are termed the *abutments*, and the intermediate supports of the arches are termed the *piers*. The walls which sustain the embankments of the approaches, where they join the bridge, are termed the *wings*. The *faces* of the bridge up and down the stream are sometimes called the *head walls*. The projections of the piers beyond the faces are termed the *cutwaters*. The centre line of a bridge between its extremities is termed the *axis*. The under side of an arch is called the *intrados* or *soffit;* the former term being used when large arches, like those of a bridge, are spoken of, and the latter for small arches, such as usually occur in buildings. The outside of an arch is called the *extrados* or *back*. The two lowest extremities of an arch are called its *springings* or *springing lines*. A line extending from the springing line on one side of an arch to the springing line on the opposite side, is called the *span* of the arch. The *crown* of the arch is the part most remote from the spanning line, and the parts of the arch for a certain distance up each side from the springing lines are called the *haunches*, but their extent has never been accurately defined. The *spandrels* are the spaces contained between the extrados and a horizontal line from the crown. The *blocking course* is the portion of the side walls between the crown of the arch and the bottom of the parapet.

Site.—When the place where a bridge is to be erected, is not determined by the position of a line of communication which cannot be altered; then, the site which offers the most security for the foundation, and the greatest economy in construction, is to be preferred. If the piers can be built on rock, a very great saving will be effected in the cost of the bridge. As a general rule, a straight reach of the river is to be selected, and a place where the bank is high on both sides. If the bridge cannot be built in the middle of a straight reach, it will be better to place it near the lower end rather than at the upper. A wide part of the stream should be preferred to the narrow part, because the water at the narrow part has not only a greater velocity than at the other, but that velocity would be increased by the space which the piers would occupy. The axis of the bridge should be placed perpendicular to the thread of the stream, where the locality will admit of its being done;

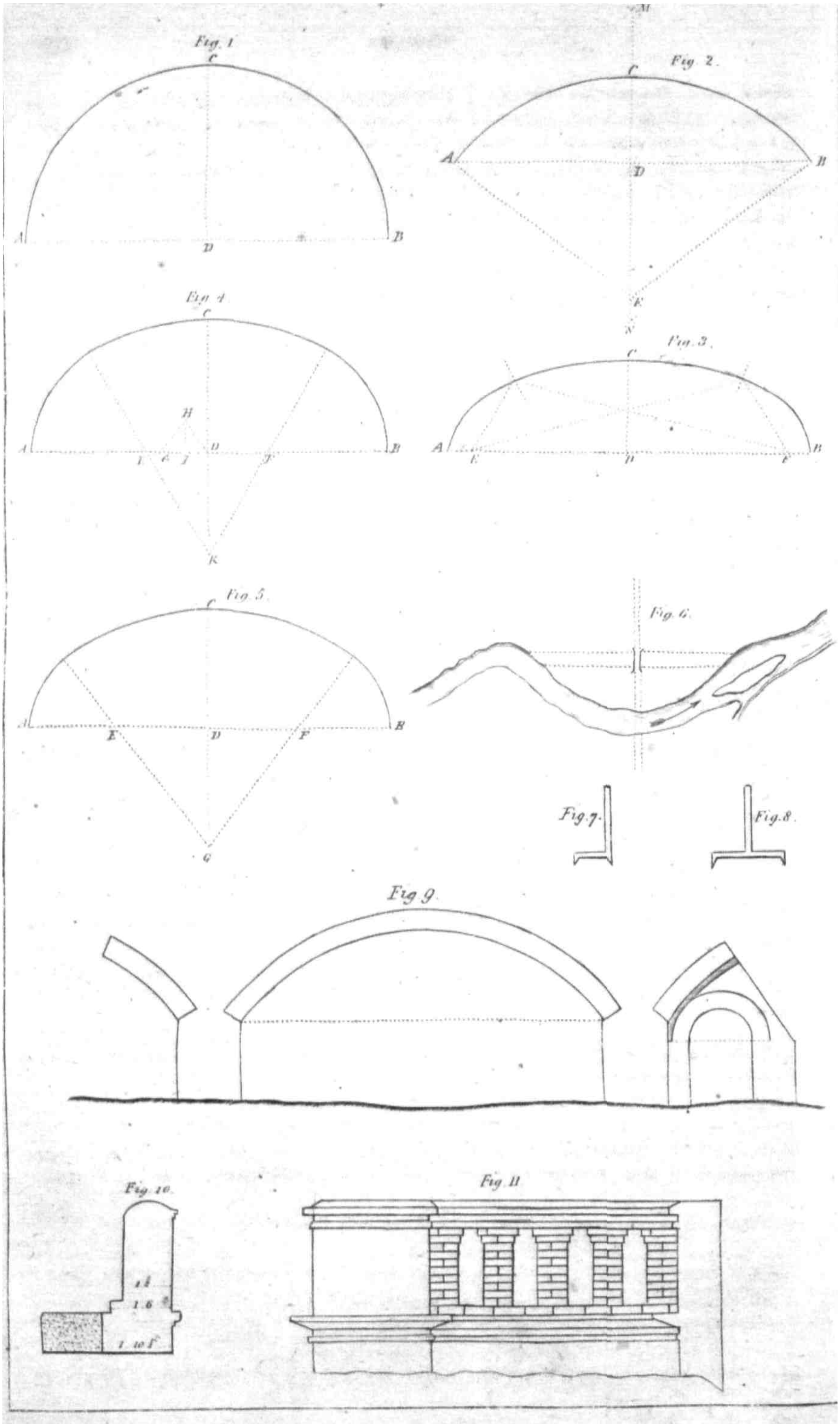
Fig. 1
C
A
D
B
Fig. 2
M
C
A
D
B
E
N
Fig. 4
C
H
A
E
G
I
D
F
B
K
Fig. 3
C
A
E
D
F
B
Fig. 5
C
A
E
D
F
B
G
Fig. 6
Fig. 7
Fig. 8
Fig. 9
Fig. 10
1.6
1.10 F
Fig. 11

when this cannot be effected, the bridge is termed *askew* or oblique, because the sides or faces of the piers which must be parallel to the thread of the stream, in order that they may not be exposed to the effects of the water striking them obliquely, are oblique to the axis. Sometimes the bridge may be built on a neck of land, formed by a bend of the river, and a new channel, leading under the bridge, must afterwards be cut for the water, and the old one wholly or partially filled up (Fig. 6, Pl. XVII). No certain rule can be given for determining when this plan should be followed; for, while it does away with the necessity for a dam across the river, and secures the work while in progress from injury by floods, yet these advantages may be more than counterbalanced by the expense of turning the course of the river.

Of the Form of arches, and the method of setting them out.— The forms usually given to the arches of bridges are those of a semi-circle, of the segment of a circle less than a semi-circle, and of a semi-ellipse. The semi-circular arch is easy of construction, presents great stability, and springing from a horizontal surface, the load acts perpendicularly, and, therefore, the arch has little tendency to spread or exert lateral pressure against the abutments. It cannot be often adopted in the construction of bridges, except when the side banks of the river are considerably elevated above the surface of the water, for the rise being equal to half the span, the roadway would be inconveniently raised; or if lowered to avoid the heavy embankments for the approaches, the stream would be obstructed by the wide spandrels. From the beauty of its form, it is always adopted in arcade verandahs and similar situations. The segmental arch, if made with a great rise, is open to the same objection as the semi-circular, and if made very flat, presents less strength and causes a great pressure or horizontal thrust against the abutments, but with the span and rise duly proportioned, it is the form which should be most generally adopted. The semi-elliptical arch gives more waterway than the segment of a circle of the same span and rise. It is well suited to rivers that are broad and shallow, with low ill defined banks, such as many of those in Southern India, but it is more troublesome to build than the segmental arch, as the joints are not all directed to the same point, and should not be adopted where the situation allows a choice between the two.

A semi-circular arch may be set out in the following manner. On a piece of level ground, draw a line as AB (Fig. 1, Pl. XVII) equal in length to the span, and find its centre D; next take a piece of string and fasten two nails to it, at a distance apart equal to AD or DB, then if one of the nails be held at the point D, the semi-circle can be described on the ground by the other, keeping the line the while evenly stretched. If the arch be the segment of a circle, draw as before a line AB (Fig. 2) to represent the span, then with the centres A and B and a line somewhat greater than the half span (using, however, the same radius in each case) describe circles intersecting each other in M and N. A straight line joining these two points will bisect AB at right angles. From D, the point of bisection, take DC equal to the proposed rise of the arch, then a circle passing through the points A, C and B may be described from a centre E, somewhere in the line MN, and the point

may be found by trial or by calculation.* To set out an ellipse, draw a line AB (Fig. 3) equal to the span, and in the middle at right angles (in the same way as in the last case) another CD to represent the rise. With C as a centre, and radius equal to AD or DB, describe a circle intersecting AB in E and F. These two points will be the foci. If two nails or pegs be fixed in the foci, and a line attached to them equal to AB, then the curve traced by a nail, keeping this line stretched, will be the ellipse required ACB. AB is called the transverse axis and CD the semi-conjugate. There are other methods of drawing an ellipse, but they are not nearly so expeditious. Curves formed of arcs of circles of unequal radii, and similar in appearance to the ellipse, are sometimes adopted for the arches of bridges. They have some advantages over the ellipse, as with the same rise and span, they may be constructed to give a greater waterway, and the direction of the joints of the masonry is more easily arranged. They may be described with three or a greater odd number of centres. The number of centres will depend on the relation between the span and rise: when the latter is one-third, or a greater fractional part, of the former, three centres may be used; but if the rise is less than one-third of the span, then five or a greater odd number must be taken. In practise, it will be found troublesome to describe arcs from a large number of centres, nor indeed will occasion be found for using curves of this description. The following is a method of describing a curve composed of three arcs, each of sixty degrees. Let AB (Fig. 4) represent the span and CD the rise. Take DG = AD — DC and on it describe the equilateral triangle DGH, let fall the perpendicular HI and take IE = HI. In the same way the point F is found. On EF describe the equilateral triangle EFK, then E, F and K will be the three centres required. If the oval arch rise one-third, bisect the half spans AD and DB (Fig. 5) in the points E and F, and produce versed sine CD to G making DG = DC, then E, F and G will be the three centres with which the curve may be described. In setting out arches, the practical difficulty arises from the elasticity of the string. Instead of the string, a piece of soft wire, about a tenth of an inch in diameter, might be used with advantage, but this is an article not always at hand in India. When the radius does not exceed twelve or fifteen feet, a slip of wood might be used.

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* Given the chord and height of segment, to find the radius of the circle. To the square of the half chord, add the square of the height and divide the sum by twice the height.

Example.—Given AB (Plate XVII, Figure 2) = 36, CD = 9, then

$$CE = \frac{AD^2 + CD^2}{2\,CD} = \frac{324 + 81}{18} = \frac{405}{18} = 22{\cdot}5.$$

The chord and height of a segment being given, to find the chord of half the arc. To the square of half the chord, add the square of the height and the square root of the sum will be the length of the chord of half the arc.

Example.—Given AB = 36, CD = 9

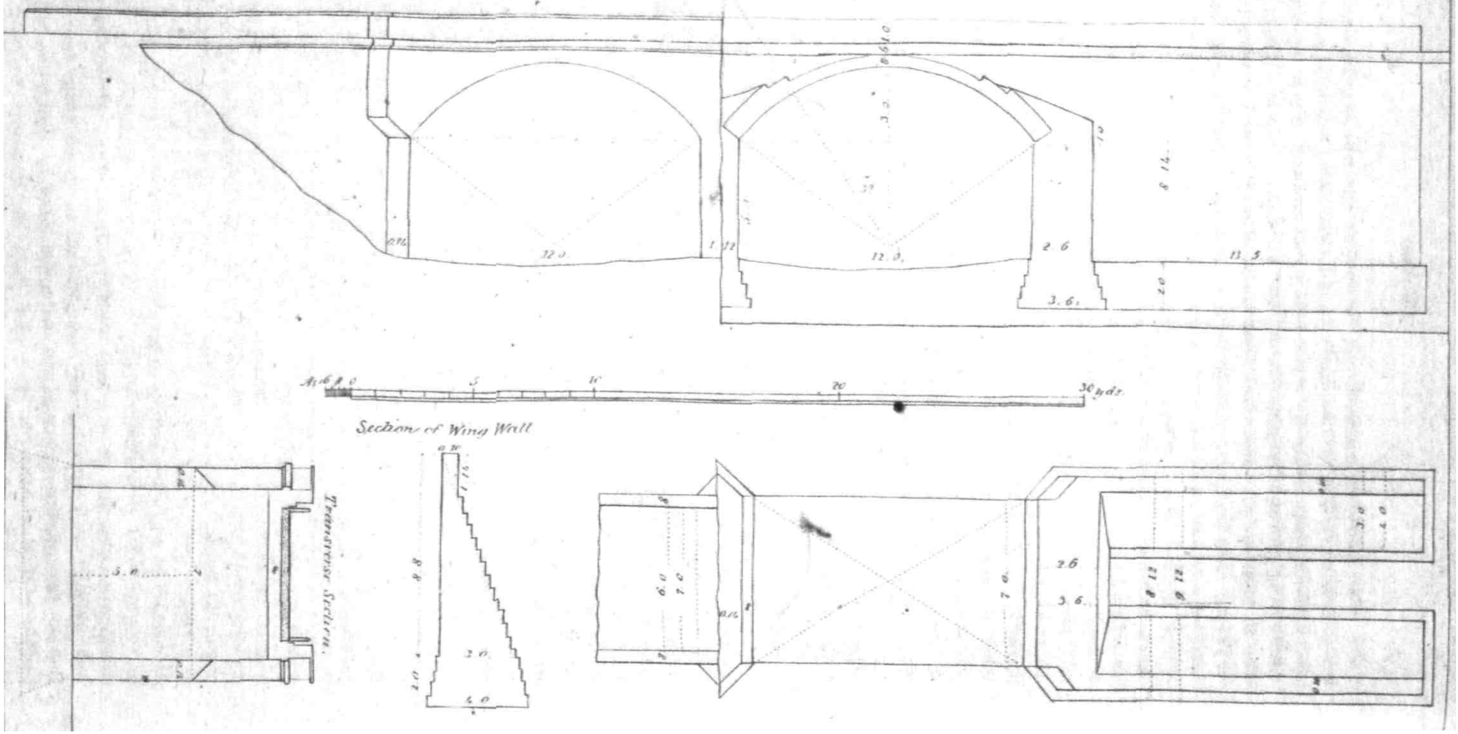
$$AC = \sqrt{AD^2 + CD^2} = \sqrt{18^2 + 9^2} = \sqrt{405} = 20{\cdot}1246.$$

To find the length of an arc of a circle, the chord of the arc and the chord of half the arc being given. Subtract the chord of the whole arc from 8 times the chord of half the arc, then will one-third the remainder be the length nearly.

Example.—Given AB = 36, AC = 20·1246

$$ACB = \frac{8AC - AB}{3} = \frac{161 - 36}{3} = 41{\cdot}66.$$

PLAN ELEVATION and SECTION of a BRIDGE of TWO ARCHES



Thickness of arches.—All small arches should be 1 foot 6 inches, or 2 bricks, thick at the crown, and this thickness will be sufficient (as experience has shown) until the span exceeds 36 feet, and then the thickness should be increased half a brick for every 8 feet; therefore for a span of 60 feet, the thickness should be 3½ bricks, or 2 feet 7½ inches. Arches are rarely built of a span exceeding 70 feet in India, and hence four bricks may be taken as the maximum thickness. Various rules have been given for determining the proper thickness of arches from the crown towards the springings, or, in other words, for determining the extrados to a given intrados, but they are seldom attended to in designing bridges, indeed some of them are altogether at variance with experience, such as that semi-circular and semi-elliptical arches must give way at the haunches, unless loaded with infinite weight. The only practical conclusion to be arrived at is, that arches should increase in thickness from the crown to the springings, for, the pressure (compounded of the weight of the materials and their tendency to thrust or extension), increases from near the crown towards the springings, consequently the quantity and weight of material must increase in a similar ratio. Besides, the spandrels, or spaces between the arches, must be filled in with masonry or earth, a great weight will thus be thrown on the haunches, while scarcely any can be placed on the crown, which might then be forced up to the destruction of the arch. To prevent this, it will be necessary to give the arch the greatest strength where it is required, that is, at the haunches, and this is done by increasing the thickness at those parts. In segmental arches, the thickness at the springing is usually half as much again as at the crown. In semi-elliptical arches, the thickness at the springing cannot be more than half that of the pier, but the thickness may be increased for some distance upwards, by producing the joints of the contiguous arches till they meet as in Plates XX and XXI. Brick arches should be divided into several portions, and the increase of thickness in each portion should be half a brick as shown in Plate XVIII in order to ensure proper bond. In small arches, the extrados may be made parallel to the intrados.

Span and Rise of Arches.—After the site of a bridge has been fixed upon, before determining the number and dimensions of the arches, it will be necessary to take an accurate cross section of the river at the intended site, and ascertain, as nearly as possible, the height of the highest floods. The latter may be found partly by observation, and partly by enquiring of the villagers in the neighbourhood; but their reports must be received with caution, as they are careless about truth and prone to exaggeration. The marks shown by them on one bank might be compared with the corresponding marks on the opposite bank, with a levelling instrument, and if found to agree, there is a presumption in favor of their being correct, but they will often be found to vary by half a dozen feet. If the river has clearly defined banks, at the place where the bridge is to be built, the faces of the abutments should be in a line with the foot of the slopes of the banks, but should the ground be low on one or both sides, so that during floods the water spreads to a considerable distance, the interval between the abutments need be only the average width of the river in the neighbourhood, measured between the banks. The crown of

the arches should be three feet above the highest floods, in order to allow space for floating bodies. It is of great importance to give a bridge sufficient height, as a considerable diminution of waterway is compensated by a little additional height while no excess of breadth is certain to make up for defective height. As to the number of arches of which a bridge should consist, no positive rules can be laid down. When possible, streams should be crossed in a single span, especially impetuous torrents among hills. In other situations, while on the one hand, the number of arches should not be unnecessarily multiplied, both from motives of economy, and in order not to offer too great an obstruction to the stream; on the other, arches of too large span will not be advisable, as they are more difficult to construct. When the foundation soil is bad, the base of the foundation must be large, and it will be cheaper to have few piers, and consequently arches of large span, but in ordinary cases, it will be better to adopt a span of between thirty and forty feet. It has been already stated that those of thirty-six feet span may be made of the same thickness that is required for smaller arches, while arches of a greater span must be thicker, and, therefore, dearer. Again, an arch of thirty-six feet is easy of construction, and its centring may be of such kind, that its erection and removal may be intrusted to a good maistry. Large arches require to be carefully superintended during construction, and the centring for them must be of an expensive description. When the span does not exceed twelve or fifteen feet, the arch should be segmental, with a rise of one-seventh, and it will then be an arc of sixty degrees nearly. The rise should increase with the span, and when that exceeds thirty feet, the rise should be one-fourth: this proportion will combine solidity with a handsome appearance. As a general rule, a bridge should consist of an odd number of arches, in order that a pier may not be built exactly in the centre of the stream, but the rule may be broken to secure a better foundation for a pier. A bridge also looks better when it consists of an odd number of arches, for an arch being the principal feature in a bridge, it should occupy the middle place.

It is now most usual to give the same rise and span to all the arches of a bridge, and to place their springing lines on the same level. This is preferable to having arches of unequal dimensions, with their springing lines lower in receding from the centre to the extreme arches. When the first plan is adopted, the parapet wall and roadway will be on the same level throughout, and measures must be taken for keeping the latter dry by apertures at the bottom of the parapets. Large embankments will be required for the approaches, when the banks of the stream are low and the rise of the arches is considerable, but as the rivers occasionally receive an extraordinary quantity of water, for the passage of which provision must be made by placing the crown of the arches well above the level of the water in ordinary floods, so to prevent the roadway of the approaches being covered, it must be raised above the river banks.*

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* The mean velocity of a stream is found by measuring the velocity of the surface in the middle, which is done by noting the time it takes any small light body to pass between two fixed points, and taking four-fifths of it for the mean. Having found the

The piers ought to be so proportioned, as to enable them to withstand the thrust of the adjoining arches, though the rest were thrown down; yet to fall short of the size required for this purpose, would hardly be a greater fault than materially to exceed it; for when piers are unnecessarily large, the current being contracted, increases its velocity, and is apt to undermine the foundation.

Piers and Abutments.—As the horizontal thrust of the two half arches on each side of a pier, counteract each other, the only effort that the pier will have to sustain will be that arising from the weight of the two half arches, with the accessory weight that may be placed over them on the road surface. The thickness of the piers at top should, therefore, in theory be only sufficient to sustain this pressure, but this is much less than what is given in practice, for, allowance must be made for wear and tear of the exterior surface of the piers, for shocks from floating bodies, for inferior materials and slovenly workmanship. The abutment having to sustain the thrust from the arch on one side only must be of greater thickness than the piers. The rule of one-sixth of the span for the piers, and one-fourth for the abutments, will be found a very safe rule, but it will in most cases give a greater thickness than necessary. It is applicable when the span is between 12 and 24 feet. Smaller arches will be considered under the head of Road Tunnels in the following chapter. For spans

mean velocity of the natural waterway, that of the artificial waterway (as that under a bridge) may be obtained from the following expression.

$$v = m \frac{S}{s} V$$

in which s and v represent respectively the area and mean velocity of the artificial waterway; S and V those of the natural waterway, and m a constant quantity, which, as determined from various experiments, may be represented by the mixed number 1·097.

The following table exhibits the velocity of stream which, under ordinary circumstances, the various descriptions of soil enumerated are capable of resisting. It should, however, be observed that the scouring influence of rivers depends not only on the velocity, but also on the depth, or weight of water resting on their bed.

The ordinary nature of current.	Velocity.		Materials that resist these velocities, and yield to more powerful ones.
	In feet per second.	In miles per hour.	
Very slow	0·25	0·171	Wet ground, mud.
Gliding	0·50	0·341	Soft clay.
Gentle	1·00	0·682	Sand.
Regular	2·00	1·364	Gravel.
Ordinary velocity	3·00	2·046	Stony.
Extraordinary and rapid floods	3·35	2·284	Broken stones, flints.
Extraordinary floods and rapids	3·45	2·352	Collected pebbles, soft schistes.
Do. do. do	3·55	2·420	Beds of rocks.
Torrents and Cataracts	9·86	6·723	Hardened rocks.

The above formula and table are often given in order to show to what extent the velocity of the water under a bridge may be increased, by diminishing the waterway. But the fact is, on the one hand, however hard the soil may be, the knowledge that he may do so with impunity, will hardly induce any one to place an unnecessary number of piers in a river, and on the other, however soft the soil may be, it may not be advisable in some situations to adopt arches of large span. In the latter case, an artificial bed must be formed for the river between the piers.

between 24 and 48 feet, one-seventh will be sufficient for the thickness of the pier, and one-fifth for that of the abutment. For larger spans, one-eighth may be taken for the thickness of the pier, but it will not be advisable to reduce the thickness of the abutment below a fifth. The abutment to a flat arch should be stronger than to one with a high rise, therefore, taking the same rule in all cases for the thickness, when additional strength is required, it may be obtained by building a buttress or counterfort at the back, but in the narrow bridges usually built in India, buttresses will not often be necessary. The back of the abutment should be built up to a height of one-fourth or one-third of the rise of the arch above the springing line, and the masonry finished off in a tangent drawn to the extrados of the arch: the tangent is sometimes drawn from the level of the springing, and occasionally arches have been left without any masonry backing, but there always should be some masonry backing. The practise of making all *abutment piers*, that is, piers having sufficient thickness to resist alone the horizontal thrust of the arches, is objectionable, on account of greatly diminishing the natural waterway, and also causing a very considerable addition to the expense of the structure. In bridges composed of numerous arches, however, it is not a bad plan to make every fifth or sixth pier strong enough to act as an abutment, as the arches can then be turned in sets, and if not all completed in one season, the remainder may be safely left till the next, and afterwards, should one arch give way, the damage would not extend further than the next abutment pier, but when no abutment piers are built, the fall of one arch may be followed by that of all the others, perhaps twenty or thirty in number. In calculating the thickness of abutments, the pressure exerted by the great mass of earth at the back, and which must act as a counterthrust to that of the arch, seems generally to have been neglected, and also the fact of the wing walls acting as buttresses; hence, an unnecessary thickness has sometimes been given. Piers, when intended to act as abutments, have no such aids, and their thickness should not be much less than a fourth of the span. When all the arches of a bridge are not built in one season, a small temporary arch must be turned on one side of the last pier (supposing it not to have been made of extra thickness) to support a portion of the next arch, to act as a counterpoise to the last of those finished (Pl. XVII, Fig. 9); or a high mass of brick in mud may be raised on the top of the last pier. The rule for the thickness of piers applies to the level of the springing. Short piers should be built with perpendicular sides, but a very high pier looks better for a batter. Piers for semi-circular and semi-elliptical arches are finished with flat tops, but for segmental arches, the tops must be fashioned to the angles of the springing lines with rubbed bricks or with bricks moulded for the purpose, and they are then called *skew backs*.

The foundations of piers and abutments, for arches of more than 2 yards span, must be according to the nature of the ground on which they are to be built. If gravel or harder soil is found at 2 yards below the surface, and not nearer, the foundations should be 2 yards deep, and their breadth, 4 annas* more than that of the wall above. If clay or

* The anna is the sixteenth of a yard—2¼ inches.

earth extend to more than 2 yards below the surface, the foundations of wing walls should not be more than 1 yard deep, but the base of the foundation must be one yard wider than the wall above, diminishing in width upwards by 2 annas on each side for every quarter yard of height. The foundations of piers and abutments, in such ground, may be $1\frac{1}{2}$ or 2 yards deep, according as the arches are small or large, and the stream sluggish or rapid. The width of these foundations will, in like manner, be determined as above, making offsets on each side of 2 annas at every eighth course. Piers and abutments will often have to be built on wells, or the lower part of the foundation formed with brick cubes—a description of these has been given in a previous chapter. Piers and abutments should not be run up too hastily, or the mortar in the bottom courses will not have time to set before the top is finished, and the masonry will become cracked.

It will generally be cheaper to build a bridge entirely in one season, than to build the piers in the first year and turn the arches the next, as certain incidental expenses, such as superintendence, constructing a dam across river, &c., will only have to be incurred once, but it will not always be possible to complete a large bridge in one season, and should there be any doubt regarding the height of the floods, it will not be desirable to do so.

Cutwaters.—The projections of the ends of the piers, or cutwaters, are sometimes made in the form of a semi-circle, or of a semi-ellipse, or with two plane faces making an angle up or down stream, or with two curved surfaces making an angle in the same direction. It will be best to make the faces form a right angle; the length of the cutwater is then equal to half the breadth of the pier. Another good shape is obtained by describing arcs from each corner of the pier, with a radius equal to its thickness. The cutwaters are sometimes carried up no higher than the springings. The top lines of the cap should be drawn to the centre of segmental arches (Plate XVIII), and when the arch is elliptical, the cap should have a very slight rise (Plate XXI). The cutwaters are sometimes carried up to the level of the roadway, and the parapet built along their edge, by which means small recesses are formed. The former arrangement is the more advisable, unless the roadway is narrow; the recesses will then be found useful in a long bridge. The cutwaters sometimes receive a batter (Plate XX), but there is no occasion for it. Coupled columns above the cutwaters, as in Plate XXI, are highly objectionable.

Spandrels.—The spandrels between the face walls are often built up to a height of about one-fourth of the rise of the arches, and above this a small arch is turned, the crown of which is on a level with the crown of the bridge arches. This spandrel arch may, in most cases, be dispensed with, and the backing of the two contiguous arches may be formed concave or dished as shown in Plate XVIII. With a view of affording more room for the passage of the water during floods, oval or cylindrical passages are sometimes made in the spandrel spaces, but the practise is not a very good one. The face walls

should be from 2 to 3 feet thick.* In filling in spandrels, from a quarter to half a yard of sand should be put between the arch and the earth used in filling. If the earth is thrown in loose between these walls, and afterwards gets wet, it will swell considerably and either push out or crack them, especially if the mortar has not had time to set. To obviate this, it will be a good plan to leave small holes at every yard in height and two yards in length of these walls, for the passage of the water, and the earth should be thrown in, in small quantities at a time, that it may become consolidated. The extrados of the arch should be protected by a casing of one brick on-edge in mortar, or by a mixture of broken brick and mortar before the earth is placed over it.

Wing Walls.—The wing walls may either be built at right angles to the abutment, or with a curved splay outwards: the first plan, which is the simplest, should generally be adopted; it has, moreover, the advantage of giving a better hold to the earth of the river banks, but, when two or more roads meet at a bridge, the wings may be curved to form a better approach. When the soil of the river banks is bad, the foundation of the wings must be laid at the same depth as that of the abutment, for their whole length, otherwise unequal settlements and cracks are likely to result from the height and weight of portions being unequal. But, if the soil forming the banks of a stream be firm, the wing walls may be cheaply and strongly built with foundations in steps, corresponding with the form of their banks. The depth of each successive step should be determined with reference to the section of the bank and to the soil; in rocky ground the surface of each step should be half a yard below the surface of the ground, and in gravel three-quarters of a yard, and the horizontal distance from the top of each step to the sloping surface of the bank should be in rocky ground about a yard, and in softer soil, rather more.

The length of wing walls should be one and a half times the height of the roadway above the bed of the river. Their thickness at bottom should be one-third of their height, and they should be built with offsets on the inside, so as to reduce the thickness at top to two or two and a half feet. When they are built perpendicularly, or with only a slight batter on the outside, the thickness may be a fourth or fifth, and it has occasionally been even less. When wing walls are built with buttresses, the usual thickness at bottom is one-fourth of the height, and the length of the buttress is the same. The former having a slope of one in four, the latter of one in two, with offsets on the inside. The breadth of each buttress may be one-half the length at the base, and the interval between two, three times the breadth. Building wing walls with offsets on the inside is preferable to building

* A face wall, like any other revetment, will have a sufficient thickness, if the wall be everywhere of thickness equal to one-third of its height, measured from the top downwards; but as this would not do if the height were less than one yard 14 annas, 10 annas may be allowed for all the wall from the top downwards to 1-14, and below that, at the rate of 2 annas additional thickness for 6 annas additional height or depth. This will be a correct rule for a road dam. The same dimensions may be given whether the revetment have an outer slope or not—with the outer slope, the wall is somewhat stronger than without it. It is strong enough if made with a base of one-third, whether it be sloping or counter-sloping, or slope both inside and outside. Inside steps are better than a smooth sloped back, stronger, and much easier to build.

them with a uniform batter on the outside, as the latter plan gives the bricklayers more trouble. The thickness of wing walls should depend not only on their height, but on the description of the soil; when that is firm and compact, there will not be so great a pressure on the walls as when it is loose. Wing walls of very great thickness have been thrown down, or cracked to such an extent, that it has been necessary to re-build them, from the earth having been thrown in loose between them and swelling after becoming saturated with water. This accident would never happen if the precaution were taken of filling in the earth gradually, as the walls are being raised: it is then trodden on daily, and cannot afterwards be easily penetrated by the water. A few holes should be left for the escape of water, as recommended in the case of the face walls.

Parapets.—The height of the parapet wall above the roadway may be 3 feet in medium sized bridges, and may be increased in large ones to 4 feet, while for small road tunnels, a few inches will be sufficient. The thickness may be either a brick and a half, or two bricks, the former will generally be sufficient. On the interior side, at bottom, there should be a projection 4½ inches square to keep off the bandy wheels: (Fig. 10, Pl. XVII). The blocking course, on which the parapet is built, should be 1½ to 2 feet wide, and from 1 to 2 feet high. The inside of the parapet should be quite plain, as any projecting ornaments would be quickly knocked off: on the exterior side, at top and bottom, a neat cornice will improve the appearance of the bridge. Should a balustrade be adopted instead of the ordinary parapet wall, it should be formed of bricks moulded expressly for that purpose: hollow pottery balusters are very trumpery, and should be altogether rejected. There is no objection to perforated parapets, built with the common bricks (Pl. XVII, Fig. 11): they have a pleasing appearance, and prevent an accumulation of dust on the road. If the parapets are more than 5 yards long, holes should be left over the crown of the arches, and at every two yards length of the wing walls. These holes are for the purpose of letting the rain water drain off the road. The bottom of the holes should be about an inch below the level of the road surface, and if there is a cornice, the water should issue underneath it. As soon as the parapets of a bridge or tunnel are completed, whether plastered or not, small mud parapets should be made to extend 5 yards further, along the edge of the road bank, and carried down to the bottom of the bank with a slope of 1 in 10 or more.

Brick bridges are almost invariably plastered; the objections to this practice have been pointed out in a previous chapter. The parapets soon present a shabby appearance as the plastering, especially at the top, is almost invariably wantonly destroyed by the village boys. A stone coping would be secure from injury, and would very much improve the appearance of a brick bridge left unplastered. The outside bricks would then have to be laid with regularity, and with thin mortar joints. There should also be a string course of stone, 6 inches thick, projecting 2 inches over the face of the work—the under edge about a foot or a foot and a half above the crown of the arch.

Roadway.—The roadway should be from 1 to 2 feet thick on the

crown of the arch, and should, if possible, be metalled, though the approaches are not, and the rubbish from the brick-kilns should be taken for the purpose if no better material is procurable. Four granite guard stones are required to be fixed in the road, either at the extremities of the parapet, or at the parts where the roadway begins to narrow, to protect the parapets from the bandy wheels. All small road tunnels should be made the full breadth of the road, whatever that may be, but from motives of economy, the breadth of the roadway over bridges has of late been restricted to 18 feet.* The breadth of the arches must, therefore, be 21 feet, to allow of the space taken up by the parapets.

When the roadway over a bridge is much higher than the country adjacent, sloping approaches may be necessary. They should not be steeper than 1 rise to 20 base. If the bridge have but one arch, the roadway over it should always be horizontal, the slopes beginning over the abutments. If there are more than one arch, the slope may begin near the crown of the outer arches, the remainder of the roadway over the centre arch being horizontal—always horizontal over the others also, if the arches be of the same height; otherwise, raised to an equal height above the crown of all of them.

The common breadth of bridges is about thirty feet; but when they form the avenues to large towns, the carriage road is nearly this breadth, and they have besides a raised foot-path from six to nine feet broad on each side. The parapets are parallel for the greater part of their length, in the middle; but at each end they diverge, in order that the increased width of the road thus obtained may render the entrance upon the bridge more free, and unite better with streets, which are commonly wider than bridges. The wide parts of the ends are generally supported by the solid abutments alone.

Flooring.—When there is a likelihood of the bed of the river between the piers being scooped out, by the force of the current, a pavement of loose stone, or brick in chunam, protected by retaining walls, must be placed between each pier. The retaining walls, about 2 feet in thickness, are to join the cutwaters of one pier or abutment to the next, being built in the same line as the foundations of the wing walls. They will have to be built on wells or not, according to the soil. The top of the retaining walls should be half a yard below the level of the river's bed. Before laying the floors, the ground between the retaining walls, piers and abutments should be cleared out to a depth of a yard. The flooring, if of brick and chunam, should be half a yard thick; its surface will then be half a yard below the river's bed, which is to allow for the deepening of the bed which usually follows the construction of a bridge. The flooring should consist of six courses of bricks laid flat, and one course laid on edge. The surface may be smeared over with a mixture of quick lime and jaggery, in the proportion of six viss of jaggery to a parah of lime, and rubbed with a half burned brick, till it is smooth and dry.

* A breadth of only 18 feet would be found very inconvenient, when the bridge is of great length and the traffic on it considerable.

Table of dimensions (in yards and sixteenths) for Bridges of brick or stone in mortar, adopted by the late Captain Best, *on the Trunk Roads.*

Span.	Rise or versed sine.	Breadth of Piers.	Breadth of Abutments.	Mean thickness of arch.	Length of Key.	Height of Parapet and cornices.
2 0	0 5	0 8	0 8	0 6	0 6	0 8
2 8	0 6	0 8	0 10	0 6	0 6	0 8
3 0	0 7	0 8	0 12	0 6	0 6	0 8
3 8	0 8	0 10	0 14	0 8	0 8	0 8
4 0	0 9	0 12	1 0	0 8	0 8	0 8
5 0	1 0	0 14	1 4	0 8	0 8	0 10
6 0	1 8	1 0	1 8	0 8	0 8	0 12
7 0	1 12	1 2	1 10	0 9	0 8	0 14
8 0	2 0	1 4	1 12	0 9	0 8	1 0
9 0	2 4	1 6	1 14	0 9	0 8	1 2
10 0	2 8	1 8	2 0	0 10	0 8	1 4
12 0	3 0	1 12	2 6	0 10	0 8	1 6
15 0	3 12	1 14	2 8	0 12	0 10	1 8
15 0 to 30 0	$\frac{1}{4}$th span.	$\frac{1}{8}$th span.	$\frac{1}{6}$th span	$\frac{1}{20}$th span	$\frac{1}{24}$th span	1 8 to 1 10

CENTRES FOR BRIDGES.

From the nature of an arch, formed of separate pieces of material, as bricks or stones, it is clear that they could not be placed in the position they are intended to maintain, without some artificial support for them to rest upon, until the arch is completed and made capable of supporting itself. And when that is done, this artificial support has to be removed, in order to throw open the space, that has been arched over without any impediment. This applies equally to all arches or vaults, from the smallest to the largest, and the artificial support that is thus made use of is as a whole called the *centre*, or *the centring of the arch.*

In all centring, the two chief points to be attended to are, that its upper or bearing surface shall be very correctly formed to the figure assigned to it, whether it be a portion of a circle, ellipse, or any other curve; and that it shall be sufficiently strong to bear the weight of the materials the arch is to be composed of, together with the workmen, tools, and other things that may be placed upon it, without sinking or changing its form.

In the construction of centring for small arches, little or no skill is necessary. For supporting the arches that are met with in house building, centres of the kinds shown in Figures 1, 2, 3, (Plate XIX) may be adopted. These require no description. For the arches of small road tunnels, it will be sufficient when the side walls are built, to fill in the space between with earth, and having brought the upper surface to the required shape, the arch may be built on it, and when completed, the

earth is to be removed. But a better plan would be to have a wooden centring made, from 6 to 9 feet in length, consisting of laths nailed on to the upper surface of a series of moulds of the required curve. In building the drain or tunnel, the centring is first to be fixed in its proper place, at one end of the work, and the arch is then worked over its whole extent. That done, the centre is *struck* (which is the technical expression for releasing and taking down centring) and it is moved forward very nearly its own length, taking care to leave an inch or two of one of its ends underneath, but in contact with the under side of the portion of arch that has been built. In this new position, it is to be made straight and level and again fixed; when a second quantity of arch work equal to its length may be built upon it, when it is again struck, advanced, adjusted, and is fixed and is ready for a third length of work, and by this process a tunnel may be continued any required distance with only one short centring. Two or three centrings of this kind will be found very useful, when a large number of tunnels of the same span are to be built on a new line of road.

For larger spans, the centring most in use is formed by building a wall, or set of pillars, of brick in mud, in contact with the pier or abutment, and two or more others in the space between; wall plates are then placed over these transversely, and they are connected together by palmyras, or other timbers, over which is built a mass of brick in clay, having the upper surface plastered with clay, and brought to the exact shape of the intrados of the arch; a little sand is then sprinkled over it, and after being left for a day or two to dry, it is ready to build upon. When the span is inconsiderable, there is no objection to this kind of centre, as it is easily constructed and is economical; nearly all the bricks in the pillars, &c., as they are only set in clay, can be used afterwards to complete the bridge. In rivers subject to sudden freshes, it will be advisable to build the lower part of the centring pillars of brick in chunam, or at least to point them with chunam; as mud alone will not answer in water. In Plate XIX, Figures 4, 5 and 6 are longitudinal sections of such centrings, and Figure 7 is a transverse section of the same as Figure 6. When the arch is completed, the earthen mould is excavated from below the crown, working thence towards the haunches, and by equal gradations on either side, otherwise the arch might settle unequally and be strained. This is but a clumsy way of removing the centring, and it is not always successful; a better plan is to place wedges under the wall plates or summers, and their removal will cause the arch to subside gradually, care being taken to move first those under the crown.

When the span is over 30 feet, it will be advisable to adopt a centring, composed of four or five timber frames, constructed upon horizontal tie beams, supported in several places by brick in mud pillars: the frames to be connected transversely by braces and struts, and at top, by palmyras or other timbers, supporting a stuffing of brick in clay plastered and fashioned to the curve of the intrados. Between the pillars and the tie beams, there should be placed single or double wedges, or blocks with wedge-formed steps cut in them. When these centres are to be lowered, supposing single wedges have been placed with their smaller ends projecting as in Plate XXIII, the workmen strike back the wedges by blows on the smaller end, but if the larger

CENTRES for ARCHES.

Fig. 2.

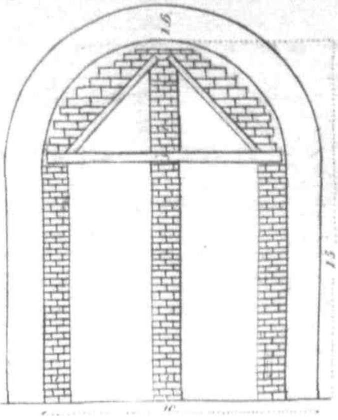


Fig. 1.

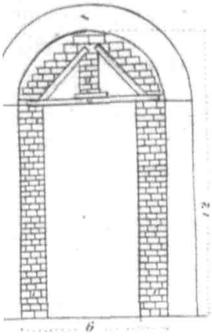


Fig. 3.

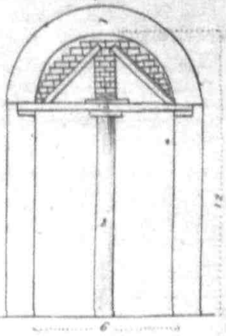


Fig. 4.

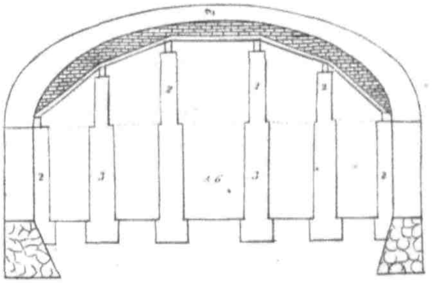


Fig. 5.

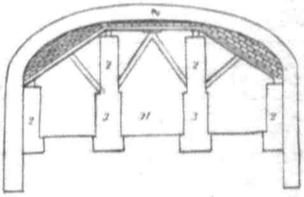


Fig. 6.

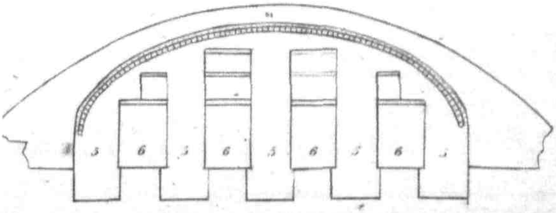
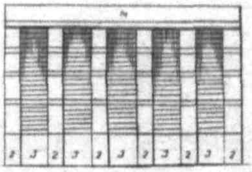


Fig. 7.



Scale to Fig. 1.2.3.

0 5 10 15 Feet

Scale to Fig. 4.5.6.7.

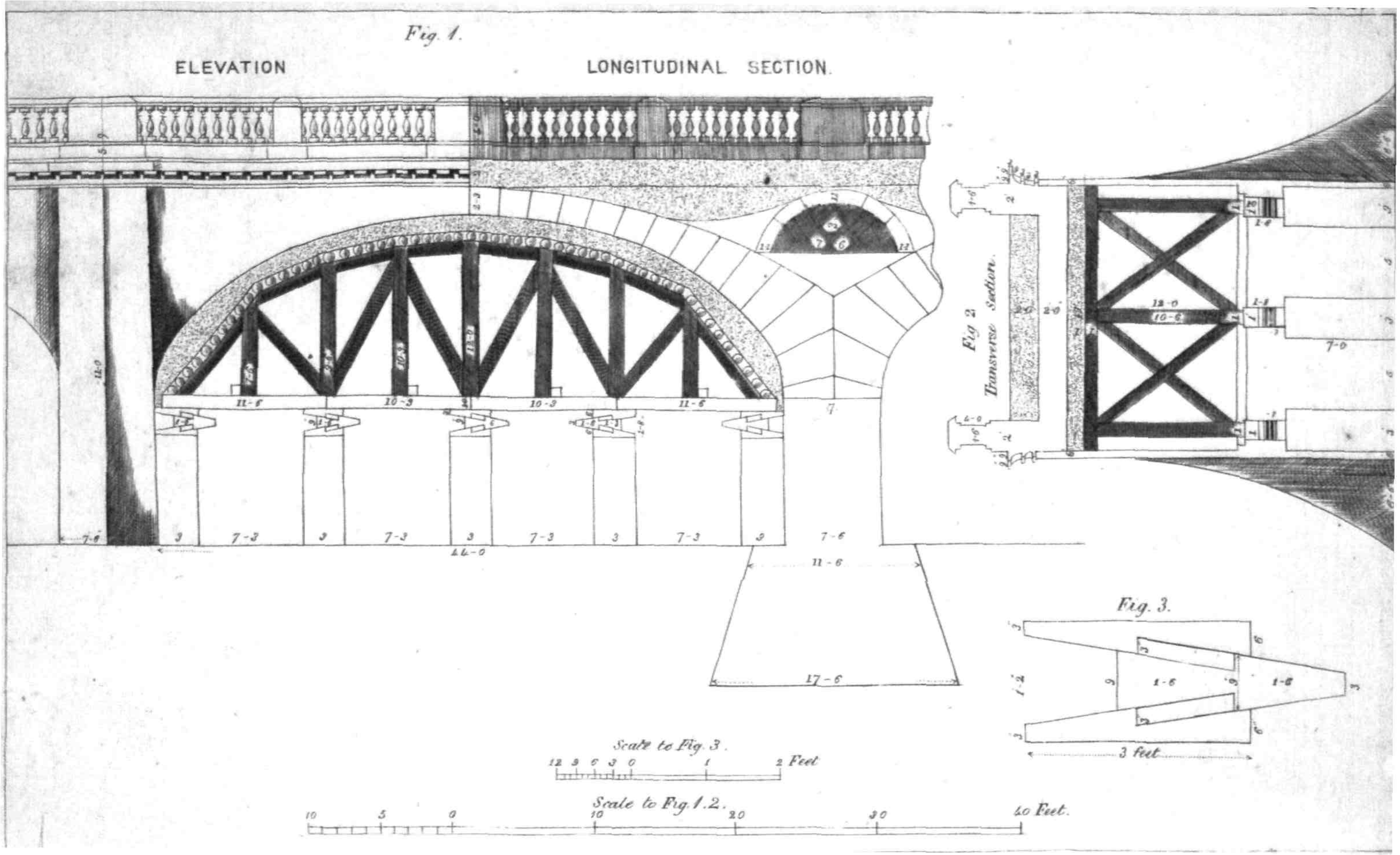


Fig. 1.
ELEVATION
LONGITUDINAL SECTION.
Fig 2
Transverse Section.
Fig. 3.
3 feet
Scale to Fig. 3.
2 Feet
Scale to Fig. 1. 2.
40 Feet.

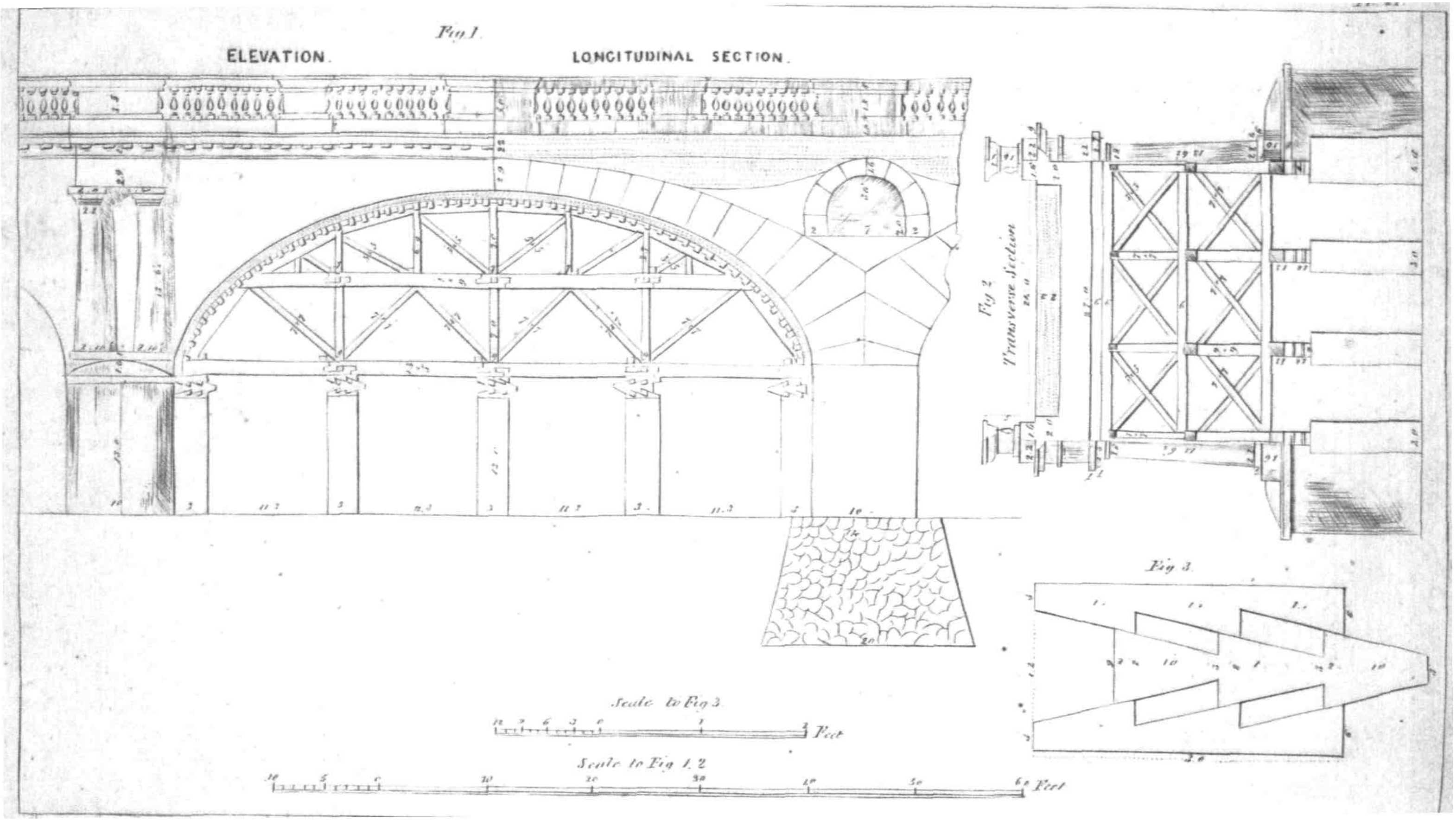
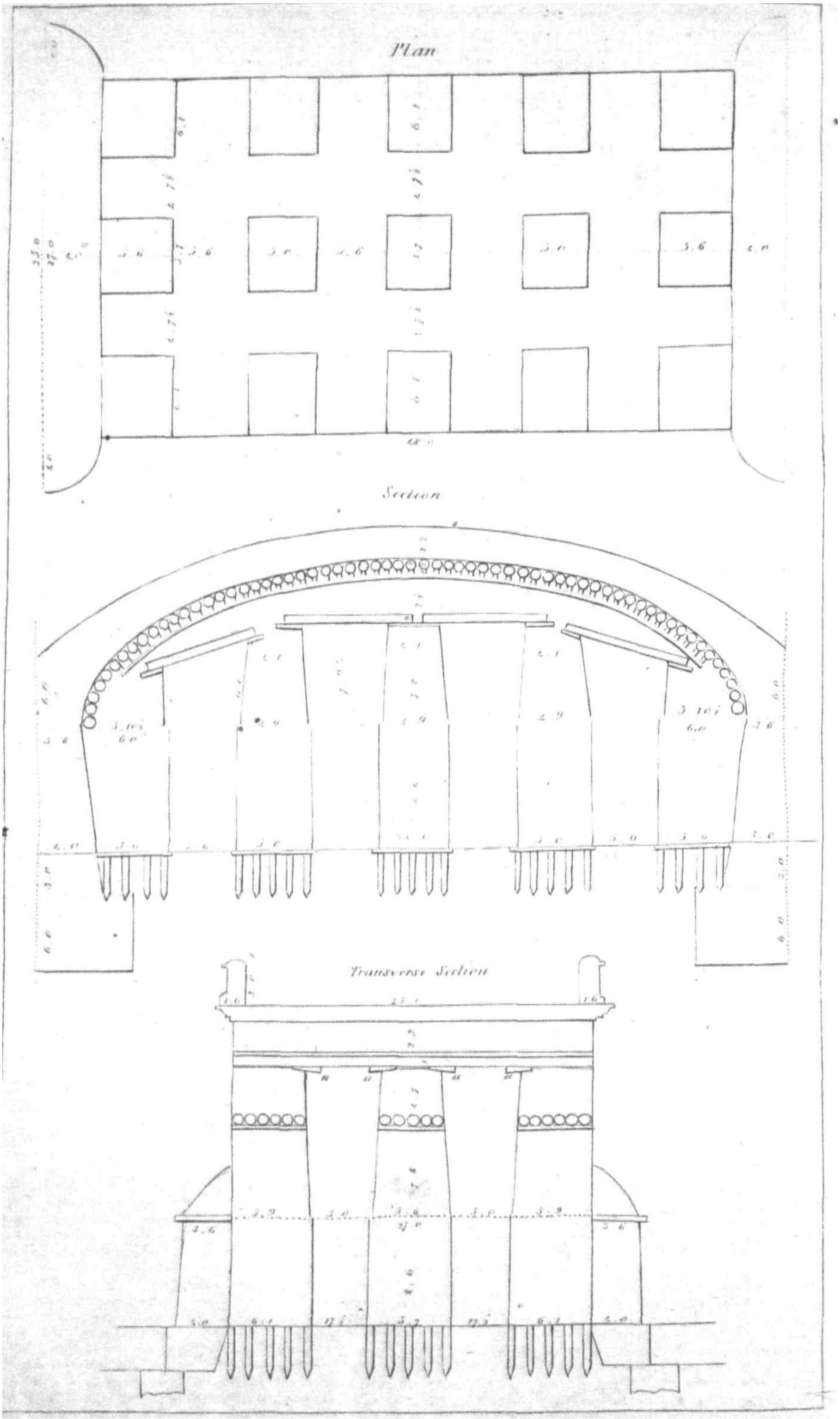


Fig. 1.
ELEVATION.
LONGITUDINAL SECTION.
Fig. 2
Transverse Section
Fig. 3.
Scale to Fig. 3.
Feet
Scale to Fig. 1. 2.
Feet


Plan
Section
Transverse Section

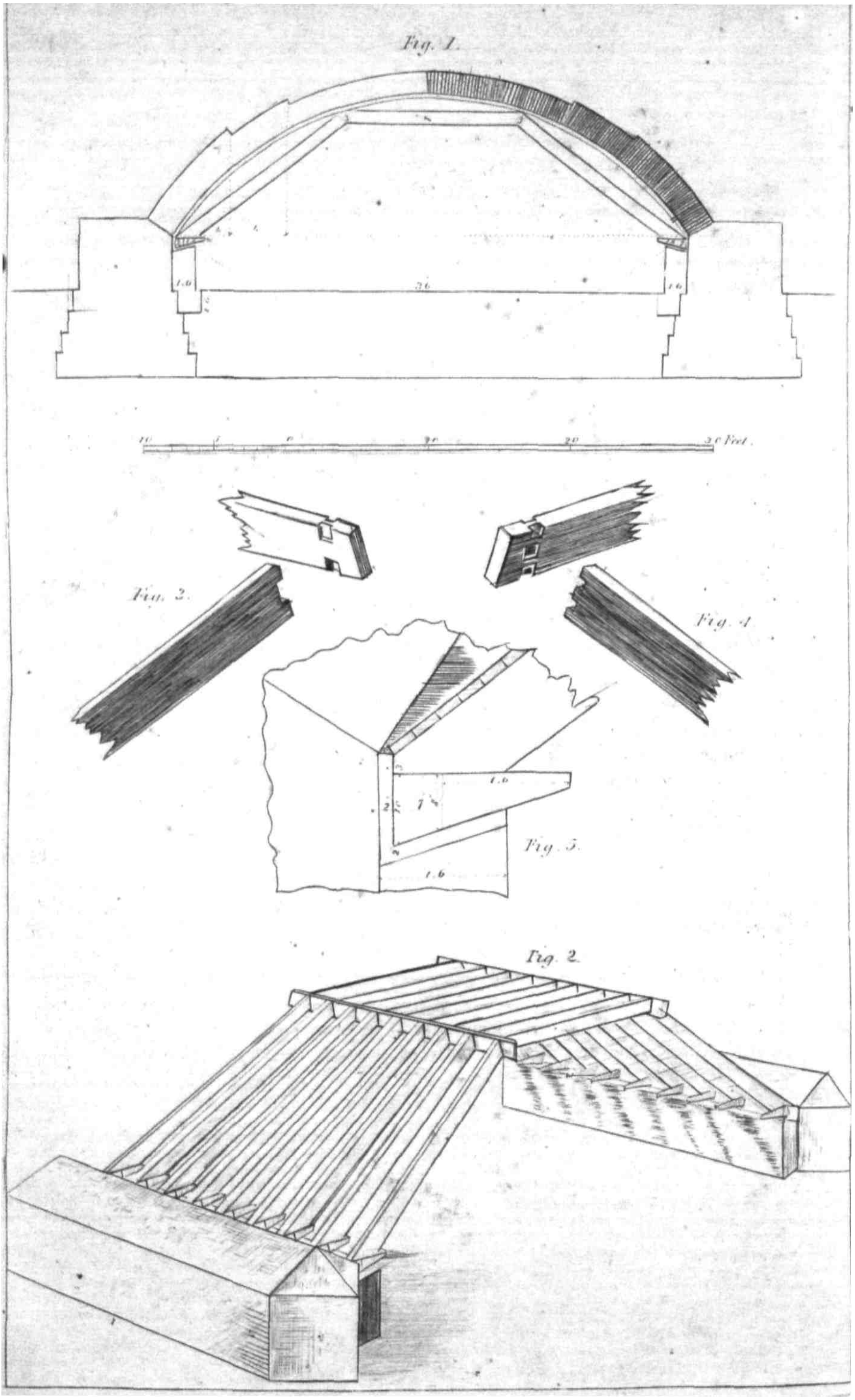


Fig. 1.
1.6
36
1.6
10 5 0 10 20 30 Feet.
Fig. 2.
Fig. 4.
1.6
Fig. 5.
1.6
Fig. 2.

end projects, as in Plate XXII, they are struck on the sides and gradually pulled outward. When double wedges are used, the upper one is placed with its smaller end projecting beyond the larger end of the lower one, and the upper wedge is struck back by blows of a mallet on the small end. The wedge blocks are struck back in the same way. There should be a sufficient number of workmen to allow of all the wedges being moved at the same time, and they should be driven equal distances, an inspection of the arch being made during the whole process. The amount of sinking at the crown should always be noted. The wedges should be made of hard wood, and the beam above should also be hard and smooth: if a rough palmyra is placed on the top of a badly formed wedge, there will be the greatest difficulty in getting the latter to move at all. In Plates XX and XXI are drawings of centrings of the above kind which have been recently used; the scantlings of the timbers are all given, and the form of the wedges is shown more clearly, on an enlarged scale, in Figure 3 of the plates.

Another description of centring is shown in Plate XXII. Its chief peculiarity consists in the disposition of the wedges, which are placed all along the extrados of the centring, immediately under the timbers *(laggings)* which lie transversely. The wedges are shown at *a a a in the transverse section. The only drawback to the centring is* the number of wedges required, but this is more than compensated for by its certainty and safety.

As the rivers in Southern India are dry or nearly so for some months in the year, great facilities are offered for the construction of centrings, as temporary pillars, forming intermediate points of support, can in most cases be constructed; but when, from the quantity of water in the river, they cannot be built, the centring must then be supported by the bridge piers, or by piles in immediate contact with them. Such centrings are expensive, and require considerable skill in execution, the principal point to be kept in view being, to fix the timbers so that ths frames may support without changing shape, the varying weight that is to come upon them, and the difficulty of constructing them increases with the size of the arch. The necessity for using such centres rarely exists in India, and they are besides inferior to the ones previously described; they are only required for navigable rivers, where a certain space must be left for the passage of vessels, and in deep and rapid rivers, where it is difficult to establish intermediate points of support, and where sudden floods are to be apprehended.

An exception must, however, be made in favor of a centring, designed by the late Captain Best, and which has been successfully used, on several occasions, during the last two or three years.* In Plate XXIII, Figure 1 is a longitudinal section, and Figure 2, a perspective view of the centring, which consists of a series of ribs each composed of three planks, of which the upper one is horizontal, and notched at each end into two planks placed transversely, to which the other two planks, forming the rib are also notched at their upper ends and have their lower ends resting on wedges, placed on a tem-

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* This appeared in the first Edition published about 1850.

porary brick in mud wall, pointed with chunam, in contact with the pier or abutment. Planks or palmyra pieces are laid over the ribs at right angles to support the usual stuffing of brick and mud.

In setting up the centring, the two transverse planks are first fixed, and for this purpose a light scaffolding will be necessary which may be formed almost entirely of bamboos, and as soon as the centring is set up, a palmyra post must be fixed in the ground on each side and leaning against the outermost of the horizontal planks, to which it must be attached, to keep all firm.

The upper side of the wedge is horizontal, and is about three inches lower than the top of the pier or abutment, so that the upper edge of the rib just touches the springing course. The top of the temporary wall is made at the same angle as the under side of the wedge. The wedges should be arranged so as to allow of the centring being lowered not less than three inches. The ribs are placed about two feet apart and planks one foot deep and two and a half inches broad (if of good teak) will do for spans under forty-five feet. If they are of mango or other inferior wood, the dimensions must be increased a little.

The advantages of the centring consist in the simplicity of its construction and the ease with which it may be carried from place to place, and as the planks, of which it is formed, are but little cut up in being prepared for the centring, they may be disposed of, if not required for another bridge, at nearly their original value.

In building a bridge, of a single arch, over a river, it is obvious that the entire centring must be fixed at once, before the arch is commenced, and likewise in building a bridge of two arches, where the meeting or springing of both arches rests upon a pier in the middle of the river, and the other feet of the arches abut on the banks, two centrings, one for each arch, will be necessary, and they must both be fixed in their places before the arch is commenced. The reason of this is, that if only one centre should be used, resting upon the bank or shore at one end, and upon the pier in the centre of the river, on the other, and an arch should be constructed from one to the other, it would be impossible to strike and move the centring, when the arch is finished, without endangering its downfall, unless the central pier is exceedingly strong. For so soon as the centring is removed, the lateral spread of the arch will come into play, and as it will be incapable of acting on the abutment, all its lateral expansive force will be exerted against the pier, in the direction in which it is least capable of resisting pressure, and it will be overset. But by having two centrings fixed at once, both arches will proceed at the same time—an equality of load is induced on the two opposite sides of the pier, and when the centres are removed, two thrusting forces, which are equal and diametrically opposite to each other, come into action at once and neutralize each other, and the pier, therefore, remains undisturbed.

If a bridge of many arches has to be constructed, for the reasons above assigned, two centres only will be absolutely necessary, though the use of a third will be advantageous. In this case, the two or three

centres of the arches of one end or abutment of the bridge are first fixed, and the abutment arch is first commenced from both of its feet or abutments, and in doing this, a part of the second arch must also be commenced upon the first pier so as to weight it down, and at the same time to throw an equal weight on both sides of it, by which its stability is much increased; and this effect will be further augmented by also working up a small part of the second arch upon the second pier, so as to balance the second centring, and prevent its sliding away from the lateral pressure of the load placed upon it. By judicious and skilful management, the loading may be so arranged that the first or land arch may be completed, when its centring may be struck and carried to the position of the third or fourth arch as the case may be, and then the second arch from the land may be completed, and in this way, a bridge may be carried over a river until it arrives within two arches of the opposite side, when, if three centrings have been formed, one or two, as the case may be, can be fixed at once and worked up from the opposite bank to complete the work. This mode of proceeding, of course, does not apply when the central arch of a bridge is larger than the others, which diminish in size as they approach the bank; and whenever this is the case, the centrings cannot be interchanged, except by commencing operations on one side of the river, and then moving to the other, and so on alternately, until the meeting is made at the central arch. Sometimes as many as five centres are provided.

Various periods have been laid down as proper to allow between the keying and the uncentring of arches, though it has been generally agreed, that immediately after the completion of the arch, the centrings should be slacked a little by means of the wedges, so that the bricks may close in and compress the mortar. And this should be done before the facing spandrel and outside parapet walls are built upon the arches, because a trifling change of form in the arch may occur by its settlement, without impairing its strength, but which might crack and disfigure the external face walls; but if they are not built until the arch has taken its final set, there will be no danger of their being afterwards deranged or disfigured. Arches have been safely uncentred three or four days after keying, and even after twenty-four hours, and they have changed their shape but slightly; centrings have been left up to one and two months, and even six months, and though on their removal, the arches have not sunk at all, yet they have done so occasionally after the addition of the weight of the superstructure. It is clear that any change of shape in the arch must be less prejudicial to its strength, while the mortar is soft, than after it has set, for, should any settlement then take place, the work must become crippled.

From 1 to 12 days will be a proper time to allow, according to the size of the arch; leaving the centrings up longer, besides being open to the objection already noticed, increases the risk of their being carried away by a sudden fresh, from which few rivers are altogether free even in the dry season. When a large arch has been built, on an ill-contrived centring, which cannot be lowered gradually, it will then, perhaps, be advisable to leave the latter standing a considerable time; but when

proper means have been adopted for the purpose, 4 or 5 days will generally be sufficient.

If the arches have been well built, and of good materials, they will alter their shape very little on the removal of the centres, and when one hears of arches of 30 or 40 feet span, sinking six inches and more at the crown, the only inference to be drawn is, that the materials were bad or the workmanship slovenly. It has been already stated that the native bricklayers are very apt to make immensely thick mortar joints; they should therefore be carefully superintended during the construction of large arches, and this important duty should not always be intrusted to a maistry.

CHAPTER VII.

Roads.

Surveying and Marking.—In laying out a new road, or making improvements to an old one, the following points should be kept in view.

Straightness.—Other things being equal, a road should be perfectly straight, in order that its length, and the time and labor of travelling over it, may be the least possible. Unnecessary bends increase the first cost of the road and that of keeping it in repair. It will, however, be generally impossible to make a road of any considerable length perfectly straight, and if it were possible, the advantage gained by doing so would be more than counterbalanced by its inferiority in other respects, or by the increased expense of making the road equally good.

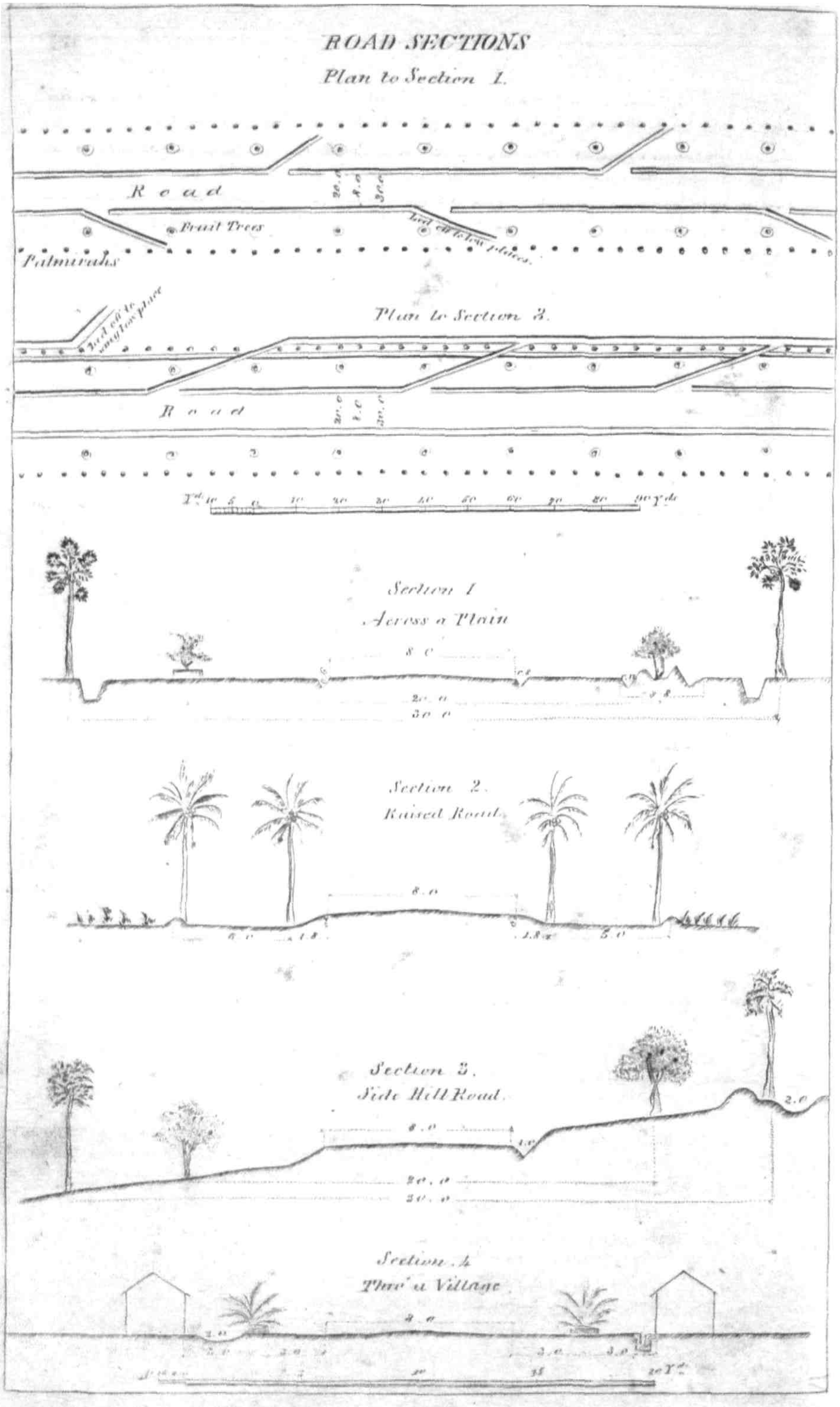
Deviations from a straight line.—For a road to be of the greatest utility, it should pass through or skirt the principal towns, to the right or left of the direct line, when by doing so, the distance between the two places, for which it is principally intended, is not materially increased, and the line of country is not less favorable, otherwise, branches must be made to connect these towns with the main road. These deviations should be regulated by considering how much traffic will be taken out of the direct road and how much brought into the new line, the relative distances, and the balance of advantage or disadvantage. If the town has a wide and straight street, the road may be taken through it, otherwise, to avoid the expense of removing houses, the road should be carried on one side. Another reason for departing from a straight line would be to avoid steep inclinations. In a hilly country, the road should wind round the hills instead of running over them. Deviations from the direct line should also be made in order to carry the road over high well-drained ground, where few embankments, bridges and tunnels will be required, and where material for the road surface is easily procurable, by which the first cost of the road will be reduced, as well as the ever-recurring expense of keeping it in repair. Minor deviations will have to be made in order to cross rivers at the places best suited to the construction of bridges. To show how little will be gained in some situations by making a road perfectly straight, it may be mentioned that if a road between two places, ten miles apart, were made to curve so that the eye could nowhere see further than a quarter of a mile at once, its length would exceed that of a perfectly straight road between the same points, by only about a hundred and fifty yards, and it would be less irksome to travel on, but this is a point on which much stress need not be laid in

intermediate points should be fixed upon, taking care to avoid, as far as possible, without making the road very crooked, wet cultivation, low swampy ground, wells, ponds, buildings of brick or stone, and handsome or valuable trees. When the latter are found, the line of the road should be taken so that they may be in the avenue, to be formed on each side of the road. It would be a good plan, at the same time, to plant a few trees, of such kind as will grow without care, as a commencement of the future avenue. Much time must elapse before the trees are of any use, and the planting of them should not be left till after the completion of the road.

The money spent in the first marking out carefully is saved over and over again, if the road is ever made, and is seldom all lost even if nothing further be done. The road has in some instances come into use for carts as soon as the line was marked, and almost invariably, the first made mark becomes immediately the favorite foot path from village to village; for the roads are made straight wherever they can be so made without additional expense and much loss of land. When the second marking is finished, the road is twice as good as the average of old roads.

Situation of Material, &c., from line of road.—While the marking out is in progress, accurate information should be obtained on many points, to allow of the estimate being prepared correctly. Among the most important of these is the position of gravel or stone fit for giving a hard surface to the road. Upon its distance or proximity will depend the cost of cartage, which is generally a very heavy item in the road work. It will not do to trust entirely to the people of the country for this information. They are interested parties, and they are often ill-acquainted with the resources of their own neighbourhood—often they do not understand what it is that is wanted. Pits, therefore, should be dug, at about 40 yards on one side of the proposed road, to a depth not exceeding 5 yards, and of size corresponding, so that the earth may not fall in upon the work people. The pits should not be more than 110 yards from one another. They will show what the subsoil is, and should it be suited for the road surface, it will generally be found cheaper to dig two or three yards of top earth off than to cart gravel from a mile distance, and so in proportion. The estimate must be made with reference to the distance and position of the material, and the rates will vary accordingly in each mile. Information should also be obtained regarding the best places for burning bricks and chunam, the prices of materials, the volume and velocity of streams, the depth of water in swamps, tanks and paddy fields, and the obstacles in the way, such as houses to be removed, land to be purchased, or compensation made.

Surveys.—Surveys in the road department are made in books, each page nine inches square within the margin, to contain one mile one furlong in length and breadth, on the scale of 8 inches to a mile, of which the last furlong in length is repeated on the next page. The object of repeating one-eighth part of the plotting is to facilitate reference from one page to the next. The surveys show the tanks, streams, nature of cultivation, position of hills, villages, &c. The channels of irrigation that cross the line surveyed are traced to their


ROAD SECTIONS
Plan to Section 1.
Road
Fruit Trees
Palmirahs
Plan to Section 3.
Road
Section 1
Across a Plain
Section 2.
Raised Road
Section 3.
Side Hill Road.
Section 4
Thro' a Village

sources if within the space that is plotted on the paper, and cross sections of them are taken with the depth of water marked.

Surveying and tracing a road will cost about 5 Rupees a mile. The further marking out by boundary channels and tree heaps costs from 35 to 100 Rupees a mile, the latter sum being 5 per cent. on 2,000 Rupees which is less than the average cost of a mile of Trunk Road.

Breadth of Roads.—By a recent order of Government, the breadth of the surface of roads passing through waste land, or land under dry cultivation, has been fixed at 8 yards, of which 6 may be metalled, and of roads passing through wet cultivation, at 7 yards, of which 5 may be metalled. In the former case, a space of 10 feet additional, measured from the outer margin of the drain, may be taken up for the deposit of material for the repair of the road, but not in the latter case. The breadth here assigned will, no doubt, be found quite sufficient for the greater part of the roads of the country, but not enough for Trunk Roads, on which there is much traffic, consisting both of goods, carts, and spring conveyances. When both carts and carriages travel the same road, it is absolutely necessary (as will be shown hereafter,) that the former should be kept to the sides, and if there were only a prepared surface of 5 yards in breadth, there would not be room for the latter between the two sets of cart tracks. On the Western Trunk Road, strings of fifty or sixty bandies may be seen constantly passing each other, and neither the mail cart nor the numerous carriages that are now on the road could travel, unless there were a space of at least 8 feet between the cart tracks. Some of the Trunk Roads have been made 10 yards wide, with 8 metalled, with a space of 15 yards on each side for ditches, avenues, and the deposit of material for the repair of the road. The sections in Plate XXV might be adopted when the land is not very valuable: when it is, less breadth must be given to the sides. It is doubtful whether anything will be gained by not metalling the whole breadth of a road, for the margins on each side, which are unprotected by the hard covering of broken stone or gravel, are in embankments very much cut up by the rain, which would not injure them if covered with metal.

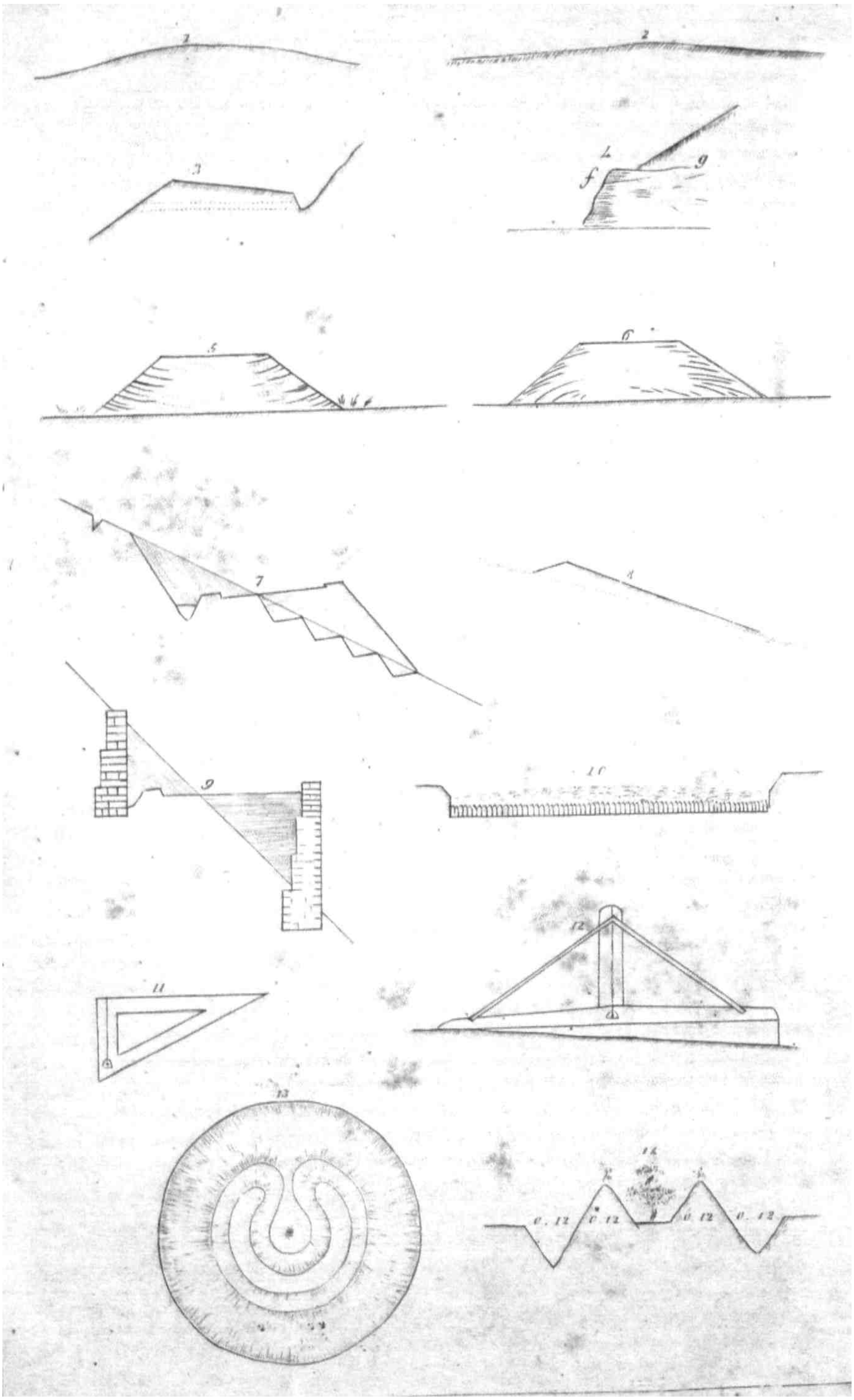
Longitudinal Slope.—A perfectly level road is best for draught, as there is a great loss of power on inclinations, and all those steeper than 1 in 30 should be avoided if possible.* A slope of 1 in 30 adds to the draught a thirtieth of the whole weight to be drawn, and doubles the labor required in drawing on an ordinary road in good condition. The resistance of gravity is always *absolutely* the same

* The following table, showing the loss of power on inclinations, is given in many books, but it is not possible to make a table like this applicable to roads in different states. Calling the load which a horse can draw on a level 1.

On a rise of 1 in 100 a horse can draw only............	·90
„ „ 1 in 50 „ „	·81
„ „ 1 in 44 „ „	·75
„ „ 1 in 40 „ „	·72
„ „ 1 in 30 „ „	·64
„ „ 1 in 26 „ „	·54
„ „ 1 in 24 „ „	·50
„ „ 1 in 20 „ „	·40
„ „ 1 in 10 „ „	·25

upon the same inclination, whether the road be rough or smooth, being the same part of the weight that the height is of the length, yet it is *relatively* less upon a rough road, and does not form so large a proportional share of the whole resistance, consequently the better the surface, the more disadvantageous are slopes. But a road *perfectly* level in its longitudinal direction is by no means desirable, for its surface could not be kept free from water without giving it too great a rise in the middle. But when a road has a proper slope in the direction of its length, not only do the side ditches readily discharge the water that falls into them, but every wheel track that is made becomes also a channel to carry off the water. By a judicious selection of the line, and setting out of the road, sufficient slope may generally be found on the natural ground; but if that is impossible, it may often be produced artificially in the earthwork. The least slope that a road called level ought to have is a yard perpendicular in a mile of length; but, as so slight a slope as this will barely affect the water, two, three or even four yards in a mile will be better, and will produce a sensible run or discharge of the water. A greater slope should be avoided if possible; because, when the slope is rapid, the water of hard rains runs with such velocity and force as to wash away part of the materials that compose the roads. A minimum slope of 1 in 80 or of 1 in 125 has sometimes been laid down as proper for a road, but it should depend on its length, and the description and state of the road surface. The latter of the above two would be three or four times too great if continued for a mile. Those parts of a road which have a moderate inclination will always be found in better order than those that are quite flat, for, scraping the surface not being practised in this country, the worn out material is washed off the sloping parts by the rain, but remains on the level parts.

Transverse slope.—If the surface of a road were perfectly hard, it might be made quite flat, for no water would lodge upon it, but as this is never the case, it is necessary to give it a slope from the centre to the sides. The usual shape given to a road in order to make it "crown" is a convex curve, approaching a segment of a circle, or a flat semi-ellipse (Pl. XXIV, Fig. 1), but this is objectionable from the slope not being uniform, too little near the middle and too much at the sides. The best transverse profile for a road on level ground is that formed by two inclined planes, meeting in the centre of the road, and having their angle slightly rounded by a connecting curve; (Fig. 2). The degree of inclination of these planes will depend on the surface of the road; being greatest where the road is rough, and lessening with its improvement in smoothness. It may also be somewhat less on a narrow road, as the water will have a less distance to pass over. It may vary between 1 in 24 and 1 in 36, or a road 24 feet in width should be from 6 to 4 inches higher in the centre than at the sides. But if the carts go on the sides (as they ought to do) the sides will be much more worn than the middle, used only by quick moving vehicles, of which the number is at present small. The slope would then become too great; to prevent this, it has been the custom on the Trunk Roads to make a third of the road in the middle at first flat, and the rest with a slope towards the sides, varying between 1 in 24 and 1 in 36, according to the material. After the road has been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0. 12
0. 12

open for traffic for some time, there will be a tolerably uniform slope from the centre to the sides. The short slopes are also much easier to lay off. But after all, there will be two ruts on each side of the road, during several months of the year, and they will interfere somewhat with transverse drainage. On a steep hill side, the transverse profile should at first be a single slope, inclining inwards from the outer edges of the road to the face of the hill. The ditch should be on the side of the hill, and its waters be carried at proper intervals under the road to its outside: (Fig. 3.) As these roads are usually made half in cutting and half in filling, if the slope were made outwards, the new earth would be much cut up by the water running over it, but after a year or two, when it has become firm, it will be better to give the surface of the road a slope both ways in the usual manner, but when the road runs down a slope, little or no cross slope will be needed.

Ditches.—The thorough drainage of a road by means of ditches is a point of the greatest importance. By attending to it alone, a road suited to all the requirements of the country can often be made; but, if it is neglected, all attempts at improvement will be useless. If the road have a covering of broken stones, the water penetrating into it makes them wear away very rapidly, by assisting the vibrating motion of their fragments. In level ground, there should be a small ditch on each side, about a foot in depth, to receive the water which falls on the road; these should communicate with others parallel to the road, made about half a yard or a yard in depth, and leading to the natural water-courses of the country. When the road is on a hill side, no ditches will be required on the lower side, but there should be two on the upper; the larger one not less than three yards from the road, and the smaller immediately along its edge, to receive the water that falls on the space between it and the larger drain as well as on half the surface of the road. The depth and size of ditches should be regulated by the quantity of water to run into them, which should be got rid of at every opportunity. As a general rule, the depth should not exceed one yard, but in level countries, difficulties may arise in getting the water discharged out of the ditches, and they may be required to be made much deeper in the progress of their fall; still, it seldom happens but that a vent or discharge of some kind may be discovered in the progress of a few hundred yards. Ditches are best made pointed at bottom, a small quantity of water has then great proportional depth, and running with more velocity than in a flat bottomed ditch, they are more easily kept clear. If the bottom of the ditch be truly cut, and kept free from grass and weeds, a fall of three or four yards in a mile will be sufficient. The soil dug from ditches should be thrown on the road to elevate it.

Side slopes.—The slopes of cuttings and embankments are designated by the proportion between the base and perpendicular of the right angled triangle, of which the slope is the hypothenuse, the base being always named first, and the perpendicular being the unit of measure. Thus, if the side of an embankment, 3 feet high, goes out 6 feet, its slope is said to be 2 to 1; if it goes out only 3 feet, it is said to be 1 to 1. The slopes of cuttings and embankments vary with the nature of the soil. Solid rock may be cut vertically. In cuttings,

when the depth is less than a yard, earth will stand better vertical than at any slope, but if *greater*, 3 and 4 to 1 will not always be sufficient. Sand requires a slope of 3 to 1 and gravel 1½ to 1. When the lower part of a cutting is in rock and has a steep slope, and the upper portion in earth has a much flatter one, a *berm** of a yard in width should be left where the change of slope takes place (Pl. XXIV, Fig. 4). For embankments, a slope of 1½ to 1 or 2 to 1 will often be sufficient, but when they are formed with light soil, it will be bad economy to make the slopes steeper than 3 to 1.

Embankments.—The breadth of the embankment at top and its height being known, its breadth at bottom will be obtained by adding the top breadth to the bases of the slopes. Two lines should be scored on the ground marking this breadth, and on each side, at the distance of one yard, two other lines to mark the ditches whence the earth for the embankment is to be taken. The ditches should be made large enough to supply all the earth that is wanted, to avoid the necessity for digging a number of unsightly pits on each side of the road. If there is good turf on the surface, it should be carefully removed to be put afterwards on the slopes. The upper soil, which will generally be worst for a road, should be removed from the whole length of the ditches, and placed at the bottom of the embankment, and not left here and there to be placed afterwards on the top. The embankment should be formed in successive layers, concave in the middle (Pl. XXIV, Fig. 5); if made convex (Fig. 6) as is usual, portions would tend to slip off, in the direction of the layers; besides, the former plan will cause the earth to be more trodden upon by the coolies passing and re-passing, and it will thus become consolidated. To make the top of an embankment level, or in a uniform longitudinal slope, the levelling instrument should be employed as it will enable the work to be done with great accuracy. When the embankment is to slope, pickets should be driven into the ground, marking the height at the top and bottom, and their difference of level ascertained, the height of the embankment at intermediate points can then easily be calculated. Pickets should then be driven in at these points, until the levelling staff placed on them gives the calculated reading. A level or uniform slope for the top of an embankment may also be expeditiously obtained with the assistance of boning staves. Portions of the embankment, at every fifty or a hundred yards, should be carefully made and after these are approved, the intermediate portions can be filled in. To form the side slopes with precision, the level† (Fig. 11) may be employed with advantage. It consists of two slips of wood, fastened together at right angles, with their ends connected by a third piece. According as the slope is to be 1½ to 1 or 2 to 1, one of the sides forming the right angle should be one and a half times or twice as long as the other. In using the level, the shortest side is to be made vertical by means of the plumb line attached to it, the hypothenuse will then coincide with the slope desired. Nothing is so objectionable in road-making as unnecessarily raising a bank above

* Berm is a term used in Field Fortification and means a space (*f g*, Fig. 4, Pl. XXIV) left between the *parapet* and the *ditch*; the breadth of the berm depends upon the height of the parapet and the nature of the soil; it may vary from 1 to 6 feet.

† This instrument will be found useful in repairing tank banks.

the surface of the country.* Banks are expensive, they take long to consolidate, delay the completion of the road and they entail the construction of numerous tunnels. Although occasionally, by means of a channel, a swamp may be drained so as to render it unnecessary to bank it across, yet in paddy fields, the beds of tanks and swamps, banks cannot always be avoided. In such places, they must be made so high that the water may not rise over, even in the heaviest monsoon. But a bank, though it be only a few inches high, if made on ground that is not subject to have water standing on it, is only injurious.

Roads through rice fields.—These must be raised sufficiently to be above the surface of the water, when the land is under cultivation, but if it is liable to be flooded during rains, additional height will be necessary; ordinarily from 4 to 8 annas above the *vurrapoos*, or raised banks between the fields, will be sufficient. Pains should be taken to construct these roads with as little injury as possible to the lands through which they pass; thus, when an old road is to be improved and straightened, the abandoned portions of the embankment should be levelled and the earth taken to form the corresponding parts of the new. The space taken up by the old road can then be cultivated at once, in lieu of the ground taken up by the new. Again, certain fields along the line of road will be often found a quarter of a yard or half a yard higher than the rest, and left uncultivated in consequence; these might be lowered to the general level of the ground,

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* There are three methods of calculating the contents of embankments; 1, By averaging end areas; 2, By the middle areas; 3, By the prismoidal formula. Thus, if a portion of embankment be 100 yards in length, 8 yards wide at top, 3 yards high at one end and 2 at the other, with side slopes of 2 to 1, its solid contents by the first method would be as follows:—

$\frac{8 + 20}{2} \times 3 = 42$ area of larger end.

$\frac{8 + 16}{2} \times 2 = 24$ area of smaller end.

$\frac{42 + 24}{2} \times 100 = 3{,}300$ the cubical contents.

2. By the second method the calculation would be thus. The average height is $\frac{3 + 2}{2} = 2\frac{1}{2}$. The mean width of the section answering to that height is $\frac{8 + 18}{2} = 13$

$13 \times 2\frac{1}{2} \times 100 = 3{,}250$ the cubical contents.

3. The rule for finding the solidity of a prismoid is—Add into one sum the areas of the two ends and four times the middle section, parallel to them; then, one-sixth of this sum multiplied by the length will be the content. In the present instance, the calculation is as follows:—

42 area of larger end.

24 area of smaller end.

$32{\cdot}5 \times 4 = 130$ four times the middle section.

196

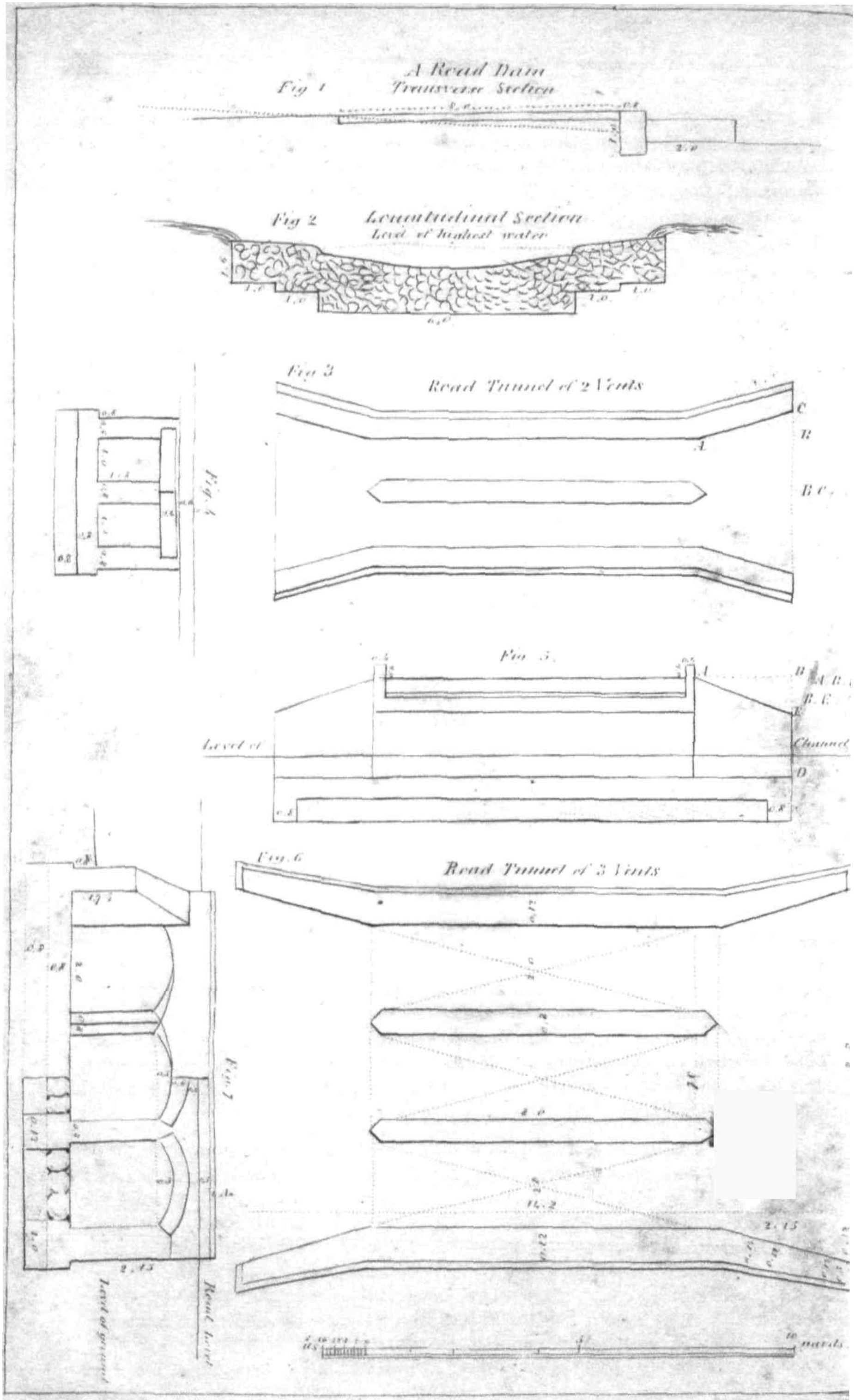
$\frac{196 \times 100}{6} = 3{,}266\frac{2}{3}$ the cubical contents.

"*The prismoidal formula*" gives the correct amount. "*Averaging end areas*" gives a result which always exceeds the correct amount, in a greater or less degree, according to the inequality of the end areas. The calculation by "*Middle areas*" gives an amount which falls short of the true one, by a deficiency equal to exactly half the excess of the preceding method. The calculation by middle areas is, however, sufficiently correct for the purposes of an estimate, but in paying for the earth-work of embankments, the best plan is to take the contents of the rectangular pits, from which the earth has been taken.

and the earth taken to form the road; the ryots will be benefitted by so doing, and in return will furnish coolies and carts for the road, but when they see a number of pits being dug in their best fields, they naturally look upon the road as a nuisance, and obstruct its progress as much as possible, by sending away the village coolies and carts to some other place. These embankments are seldom well executed when given on contract to a set of tank-diggers, for they never try to do the work well, but to do it in such manner that the amount may be readily measured. Thus, they would dig an immense number of pits in level ground, from which they would take the earth for the embankments, instead of digging ditches on the sides, for the ground there *might* be *uneven and they would fear not getting credit for the full amount of excavation, at the time of measuring the work.* Besides, they would look upon the pits as the work they were to be paid for, and would not care how the road had been formed. Sometimes from the fields being already sufficiently low, it will be necessary to obtain the earth from side ditches, and even when the greater part of the earth is got from lowering the fields, it will be advisable to dig a small ditch on each side of the road for the passage of the water from the tank. When there are no ditches, should the road be at all neglected, it will become lower than the surface of the fields, and will then be used as a channel. The side slopes after being trimmed should be turfed; turf will not grow well in the Carnatic, but it will be a protection to the slopes during the first year when they are most likely to be injured by the rain. A tunnel need not be provided for each of the channels crossing the road, but there will be no economy in providing an insufficient number, for the ryots will certainly cut the embankment wherever it is necessary to convey the water across, and the open channels will be spreading into broad pools over the road, totally ruining it in a short time.

Side Hill Roads.—When a road runs along the side of a hill, it will be most cheaply formed by making it half in cutting and half in embankment. When the ground has a uniform slope, and the side slopes of the cutting and embankment are to be the same, then by placing the centre line of the road on the surface of the ground, the amount of cutting would suffice for the embankment, but if the latter must have a greater slope, the centre line must be removed outwards, in proportion. When the embankment is likely to slip, if simply deposited on the natural surface of the ground, the latter must be cut into steps in order to retain the earth: (Fig. 7, Pl. XXIV.) This precaution is seldom taken or necessary, but it will sometimes be found useful. In adjusting the height of the made ground, an allowance should be made for its subsequent settling. If the surface be very much inclined, the cuttings and fillings may need to be supported by retaining walls, (Fig. 9) which are usually built of stones laid loose, and the largest easily procurable should be used. The thickness of the walls at the base may be one-third of the height, and they may have a batter of one or two inches to a foot.* When a road ascends

* This rule is, perhaps, not quite correct, though it has occasionally been used. The subject does not seem to have been discussed, or the theory of loose stone revetments laid down.


A Road Dam
Fig 1
Transverse Section
Fig 2
Longitudinal Section
Level of highest water
Fig 3
Road Tunnel of 2 Vents
Fig. 4
Fig 5.
Level of
Channel
Fig. 6
Road Tunnel of 3 Vents
Fig. 7
Level of ground
Road level
yards

a steep hill side by zigzags, it should be wider, by from a fourth to a half, on the curves connecting the straight portions, according as the angle between the straight portions is greater or less than a right angle.

Water Tables.—As long runs of water upon roads are detrimental to them, it is of importance that the water should be carried off them at as short intervals as possible. For this purpose water tables, (Fig. 8, Pl. XXIV) or mounds of earth, are formed across roads that have a considerable longitudinal slope, in order to turn into the drains the water which would otherwise run down and furrow up the roadway. They should be placed oblique to the axis of the road, the ridge may be from 3 to 4 inches high, and the slope such that carts may pass it without inconvenience. They may be placed 50 yards apart, if the road has a slope of one in fifty, and 30 yards apart, if it has a slope of 1 in 30, and so on. They should be formed on the road before the metalling is put on, if placed on the surface of a made road, they would be soon worn away. The road should be broken up for a distance of about a dozen yards, and then re-made together with the water table.

Road Dams.—It was formerly the custom, at the places where a road was crossed by shallow streams, running only for a few days at a time, to slope the road down on each side to the bed of the stream, and form a rough stone pavement for the water to run over. These paved dips, being made with round boulders, were exceedingly inconvenient, and so injurious to the axletrees of carts, that the drivers almost invariably preferred taking them through the mud on either side. The place of these pavements has of late been advantageously supplied by sunk retaining walls (Plate XXVI, Figs. 1 & 2) built parallel to the edge of the road, on the lower side. The walls are higher at the ends than towards the middle, and a portion at each end is made higher still, to prevent the water passing round, and as a further precaution, a turfed mound of earth is built at each end in prolongation of the wall. These dams may be half or three-quarters of a yard in breadth, and of any required depth; their length will, of course, depend on the breadth of the stream. To protect the foundation, an apron of loose stone will generally be required for the water to fall on in rear. The walls may be built either with stone or with brick, whichever is cheapest. If the nullah brings down gravel or sand, it will accumulate behind the wall, and form the road, but if it brings down mud, the mud must be removed and broken stone a foot thick substituted to form the road.

Road Tunnels.—These are to be constructed in order to allow the free passage of water under the raised road, wherever it crosses irrigated fields. It will not always be necessary to make a tunnel for every field channel that crosses the proposed line of road. Some of them may be turned and made to run parallel to the road, until a convenient place for passing them under the road, is met with. Small fields crossed by the road may need only one tunnel, but larger portions of irrigated land will require two or three at least, and an additional one, on an average, for every quarter of a mile of raised road. One tunnel should be placed where the fields are lowest, and the road

is not a very easy matter to rear an avenue on a much travelled road, for the young trees must be fenced, to prevent cattle eating them, and the sticks composing the fencès are being constantly removed for fuel. A good plan of protecting young trees is by a ditch and mud wall, as shown in Figures 13 and 14, Plate XXIV.

IMPROVEMENT OF THE SURFACE.

In many parts of the country, where the soil is favorable, by merely bridging the streams, and attending to the drainage and transverse slopes, tolerable roads can be made, answering very well for ordinary moderate traffic; but when the soil is bad, and a considerable amount of traffic is to be provided for, it may be worth while, and it is always necessary if part of it should consist of quick moving vehicles, to make the surface hard with superior materials. Clay, sand, gravel, laterite and broken stone are all used for the improvement of the surface, and in certain situations, each has its advantages. The three last materials should not be placed on a road until the earth work has had time to settle, for if placed on a newly made embankment, they will be quickly forced into it by the traffic, and the road will always be bad until thickly re-coated. An embankment will continue to settle for two to five years, and the metal should not be applied until after the expiration of the former period at least. The road bed should also be formed with the required transverse slope, for which the level (Plate XXIV, Fig. 12), will be found useful before the metalling is put on. This instrument is made by attaching to the under side of a common mason's level, a triangular piece of wood with its base and height so proportioned as to correspond to the "crowning" of the road; 1 in 24 for example. Or, instead of the triangle, gauges of different lengths, moveable on thumb screws, may be made to project below the level to proper depths. A common practise is to obtain the transverse slope by an unequal thickness of metalling, but this is objectionable, as the sides of the road to which the heavy traffic should be kept, then become the weakest parts.

Clay and Sand Roads.—If the soil be loose sand, placing a few inches of clay upon it will often be the cheapest way of improving it, and in like manner, if the soil be an adhesive clay, it may be improved by a coating of sand, and this will be found even more beneficial than the application of clay to a sandy soil, as it will render the road easy to travel on at the very time when it might otherwise be impassable. Sand and clay, in proper proportions, make always a fair road for moderate traffic. The sand must be mixed with the clay, or the clay with the sand, little by little, and in damp weather, till the proper proportion is obtained, and the road will not be good for two or three years. Sand and clay roads are inferior to those that are gravelled, or have their surface covered with broken stone, but in some parts of the country, they are the only ones that can be constructed, from the impossibility of obtaining better materials.

In making a road through black cotton soil, the first thing to be attended to is its drainage, when that has been provided for, from 4 to 6 inches of sand, if near at hand, should be placed on the surface, and this should be done, whether the improvement is to stop there, or

whether superior metalling is to come over it. Black cotton soil cracks very much during dry whether, and becomes soft mud during rains, and has been considered one of the most difficult to deal with in Indian roadmaking, but drainage by side ditches, and the coating of sand will be found a remedy for its defects. Generally friable felspar or lime stone nodules are found below cotton soil; the former is an indifferent material, but either may be cheaply applied, and will be a good preparation for a further coating of gravel or broken stone.

Gravel Roads.—The roundness of the pebbles, which form the chief part of gravel, whether from rivers or pits, prevents them from perfectly consolidating for a long time; but still a gravel road, properly made, is far superior to one of common earth. Gravel taken from pits often contains too much earth, which should be sifted from it before use. Two sieves should be provided, through which the gravel is to be thrown. One should have wires, an inch and a half or two inches apart, so that all pebbles above that size may be rejected. The other should have spaces of three-quarters of an inch, and the material which passes through should also be rejected.* So much trouble need not, however, be taken in this country. In making the road, the road bed should be well shaped and drained. A coating of four inches of gravel should be spread and carts allowed to pass over it till it becomes tolerably firm, and is nearly, but not quite, consolidated. The ruts should be raked in as fast as they appear. A second coating of 3 inches should then be added and treated like the first; and should there be much traffic on the road, a third coating may be applied. A roller drawn over the road will hasten its consolidation, and when there is no roller, wooden rammers should be used. Wet weather is the most favorable time for adding new material. Gravel may be used as a road covering until the traffic exceeds a hundred carts a day, and then it will be better to apply broken stone.

Laterite.—The roads in the town and suburbs of Madras, are nearly all made with laterite, obtained from the Red Hills and Guindy, and a thickness of from 2 to 6 inches is laid on at a time, according as the road is to be repaired or entirely reformed; for the latter purpose the usual thickness is 5 inches. When a road, or a portion of a road, is to be reformed, the surface is broken up to a depth of an inch or two and the old material thrown on the sides. The laterite is broken into pieces from 1½ to 2½ inches in diameter (the smaller sized pieces being placed at top) and while being spread, is mixed with about a sixth part of clay and well watered. A small quantity of gravel is then spread on the surface, and the road beaten with wooden rammers. Carriages are then allowed to pass over it, and the following morning, it is again beaten and rammed, and after about a week, it receives a third ramming, if necessary, and then coarse sand is sprinkled over it. The roads thus made last from two to five years according to the traffic on them, receiving occasional repairs; but

* In screening the gravel, a certain portion of loam will generally be found to adhere to the stones, and this should by no means be separated from them; for, although angular broken stones require no extraneous substance to cause them to bind, the case is different with the pebbles, of which most gravel is composed, which require a certain amount of loam or clay, to fill up the interstices between the stones, and prevent them from being rolled about, as they otherwise would be.

they are only used by spring conveyances. The goods carts are kept to the sides, which, in some cases, are formed with broken stones, but generally, with clay mixed with the material taken from the centre of the roads at the time they are reformed. When partial repairs are required to a road, the parts where the road is worn into holes are broken up, and the old material mixed with the new, and watered and beaten down in the way already described. The usual thickness of new material for repairs is 3 inches.

The following are the particulars of workmen and materials required to form one square of road of various thickness.

Thickness of Material.	Labour.		Materials.			
	Men.	Women.	Laterite Parahs.	Gravel Parahs.	Clay Parahs.	Sand Parahs.
For one square, 6 inches thick.	$1\frac{1}{2}$	$1\frac{1}{2}$	18	$\frac{3}{4}$	3	$2\frac{5}{8}$
,, ,, 5 ,, ,, ...	1	1	15	$\frac{3}{4}$	2	$2\frac{5}{8}$
,, ,, 4 ,, ,, ...	1	1	$12\frac{3}{8}$	$\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{5}{8}$
,, ,, 3 ,, ,, ...	$\frac{3}{4}$	$\frac{3}{4}$	$8\frac{7}{8}$	$\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{5}{8}$

The new parah measure is here referred to, measuring 20 inches square, and 10 inches in depth and containing 4,000 cubic inches. The Mount Road is repaired with laterite and gravel without any clay. A square $5\frac{1}{2}$ inches thick requires 16 old parahs of laterite and 8 of gravel. On the Western Trunk Road, laterite costs 1 anna 10 pice per cubic yard to quarry and break into $3\frac{1}{2}$ inch cubes, and 2 annas 4 pice to spread, water and beat down. A man and woman or boy can dig and break from 16 to $18\frac{1}{2}$ parahs (of 3 cubic feet each) of laterite in a day. Laterite roads offer little impediment to traffic, when first made, and become smooth in a day or two, and in this respect, are preferable to broken stone roads. Laterite wears quite as well as the inferior granite used at Madras.

Broken Stone Roads.—Roads made with good broken stone are the only kind which will stand very heavy traffic. These roads are as yet not very common in India, and they have seldom been constructed in such manner as to get the greatest advantage from the materials. It is considered of importance to obtain a solid unyielding bed for the material to rest on, and the best roads of this kind, in England, are formed on a paved foundation (Pl. XXIV, Fig. 10) made of stones in the shape of truncated pyramids, set on their broadest ends; the lowermost of the broken stones become wedged into the interstices between the foundation stones, and their movement being thus prevented, an immediate tendency to bind is communicated to the rest of the material. When stone for the pavement is not easily procured, its place is sometimes supplied by concrete (a mixture of broken stone lime and sand) and with equally good

results. It may not be expedient, or even necessary, in this country, to go to the expense of a foundation prepared in either of the above ways, but the principle being kept in view, the folly of placing a layer of broken stone on a newly constructed embankment is apparent. From the great heat and the absence of rain for several months together, the ground in this country is generally very hard, and if the drainage is provided for, it will do very well for the reception of the broken stone, without having recourse to a pavement, but on some clays, a coating of sand will be found useful.

Much of the goodness of these roads depends on the quality of the stone, which should be both hard and tough, and in general, those stones are best which are most difficult to break up. Granite nearly white in color is bad, as it is soon crushed to powder. Black basalt, which is found in dykes and breaks of itself in digging, answers tolerably well, but the dark colored granites, containing hornblende, are best. The stone used in this country is generally obtained by breaking up boulders, which are picked up on the sides of hills, or dug from a short distance below the surface. The stones are broken with a hammer and the size of the pieces should be cubes of about an inch and a quarter. Larger pieces (such as are used in England) will take longer to bind and will render the road very difficult for bullocks to travel on. The tougher the stone, the smaller may it be broken, and the less its size, the sooner will it make a hard road.

No metalling (or gravelling) should be of less thickness than 2 annas (4½ inches), and this only over the very best soils, and where the traffic is very light. Ordinary soils should have 3 annas and bad soils 4 annas or 9 inches. The broken stone should be applied in the following manner. The road bed having been thoroughly drained, must be properly shaped and sloped each way from the centre to the sides, so as to discharge what water may penetrate to it. Upon this bed, a coating of 3 inches of broken stone is to be spread. The traffic is then to be admitted on it, and the ruts raked in as soon as formed, or a heavy roller used till it becomes almost consolidated, but not completely so, and a second coating of 3 inches is then to be added during wet weather, as moisture greatly facilitates the union of the two. A third coating may be added in the same manner. When a road is being metalled for the first time, the broken stone will have to be spread over considerable continuous lengths, and the road will thus be very difficult to travel on, especially for bullocks which generally go unshod. To lessen the inconvenience as much as possible, a roller should always be used, and during the rolling, some gravel, or other sharp gritty very fine stuff, should be applied to the surface, without which, it will not bind. The consolidation commences with the lower part which is the first to get fixed and arranged, and when, after a few turns of the roller, the upper layers have become tolerably firm and well bedded, some sand, or stone dust, or what is best of all, sharp gravel, should be lightly sprinkled over it by degrees at every successive rolling, solely for the purpose of filling up the interstices of the broken stone, and not to cover it; about 3 cubic yards in the whole per 100 square yards (equal to about an inch in thickness if spread over the whole surface) will be required. It is essential that this small stuff be not applied earlier, or it will get to the lower strata,

and not only be wasted, but prove injurious; the object is that it should penetrate for two or three inches only, to help to bind the surface. Provided the upper interstices are filled, the less gravel used the better; therefore, it should be applied by little and little, after each of the three or four last successive passages of the roller, and then only over the places where there are open joints. The work should be done in wet weather, or the material will require to be profusely watered artificially. It will be better that it should not absolutely rain, unless very lightly, when the gravel is applied, (although the stoning should be wet,) as it will cause it to adhere to the roller, and even at times to bring up the broken stone with it. The state of the material, as regards its being wet or dry, will have great influence in the success of the operation. When a made road is to be re-metalled, which it should be when the thickness is reduced to 4 inches, instead of spreading the broken stone over considerable portions at once (which would render the road very inconvenient to travel on) it will be better to lay it down in short lengths, and allow a few days for its being worn tolerably smooth before the intervals are metalled. The surface of the road should be loosely picked previous to the spreading of the new material.

It is a common practice in this country to mix a considerable quantity of clay, sand or murrum with the broken stone, to fill up the interstices, and a road thus made is certainly fit for use much sooner than if made of clean broken stone, but it will not be so durable. Roads made with such a mixture become loose in wet weather, and allow the wheels of carriages to displace the materials, and to cut through to the original soil. The clay is washed away by the rain, or becoming dust, is in dry weather blown away by the wind, and the broken stones standing apart present a very uneven surface for carriages to travel on. Clean broken stone will, in time, combine by its angles into a smooth solid surface. A continuance of very hot dry weather, such as occurs in this country every year, is very prejudicial to a broken stone road. The crust of the road becomes so dried that it ceases to bind, and permits loose stones to be detached to the great injury of the surface. Taking into consideration the heat, the circumstance of nearly all the traffic consisting of bullock carts with narrow wheels, a roller not being always at hand, and the want of an establishment for looking after the road when made, it may be necessary to mix a small quantity of clay, gravel or murrum with the broken stone, but care must be taken that it is not in excess. In dry weather, about an eighth will be sufficient, but in wet weather, even that will not be required. Granite roads in Madras, if 5 inches thick, are formed with $18\frac{3}{4}$ parahs of broken stone and 5 parahs of murrum to every square; if 4 inches thick, with 15 parahs of broken stone, and 4 of murrum; also with 13 parahs of broken stone, 3 of clay and $2\frac{5}{8}$ of sand. One man and one woman are required per square to lay and beat down the materials.

Inequalities or hollows in the roads ought to be repaired early, and while they are small. It may be observed that these are always of a round or oval form, and, therefore, the square or rectangular patches which the workmen are usually inclined to make of them are wrong, and a waste of material. Picking up the surface before the

patching with new material should be done to the depth of about half an inch, rather more at the edges than in the middle, and if some of the finer particles can be raised and laid over the broken stone as binding, the effect will be improved. The patches will require to be watered and well beaten down. A man can dig, and break into 1¼ inch cubes, 18 cubic feet of ordinary granite in a day, and 21 cubic feet of trap. On the Western Trunk Road, the cost of spreading and rolling a cubic yard of granite is about 1 anna 9 pice. The cost per cubic yard of the material for breaking up is from 3 to 5 annas.

In India, carts drawn by bullocks, go twenty or thirty together, often in much longer strings, and all precisely in the same track, and where no rules for keeping the proper side are in force, the wheel tracks are neither on the sides nor in the middle, but zigzag from side to side, because some petty obstructions thus determined the track in the first instance. Quick moving vehicles must, therefore, either follow the same circuitous track, or going straight, be continually crossing the ruts. On some of the Trunk Roads, the rule of keeping to the left has been partially introduced, and elsewhere, if pains are taken at first, two perfectly straight wheel tracks may be established, which it will be easy afterwards to keep in repair. The middle of the road would then be left for quick moving vehicles, and the number of these at present being small compared with the goods carts, the portion of the road used by them might be kept in repair at a moderate expense if the carts were kept to the sides. The best inducement for the drivers to do so voluntarily, is to make the sides at least as good as the middle of the road. Indeed, the thickness of broken stone at the sides should be greater than in the middle, as it will be exposed to so much more wear. The part actually passed over by the wheels on the Western Trunk Road must be subject to as much wear as any road in England, where the carts go over the whole road equally. The thickness of metalling for such situations should, therefore, not be less than 9 inches. So strictly do the carts follow in the same track, and so little would the road be worn except where the wheels pass (the bullocks treading in the wheel tracks) that, with a view to economizing material, it has been proposed to provide only for the space actually passed over by the wheels. For this purpose, two trenches might be dug, a foot wide and nine inches deep, the distance apart from centre to centre being the same as the distance between the cart wheels, these trenches could be filled with good broken stone, and the rest of the road left untouched or coated with some cheaper material. It is doubtful whether this plan would answer, for unless the natural soil were very firm, it would yield laterally and the stones would not become consolidated. So, in constructing tramways with blocks of laterite or granite, it is necessary to prepare a foundation for the stones to rest upon, and the space between the trackways and to some distance on each side must either be paved or filled with some hard material, or carts going near the edges of the stones will cause them to tilt up.

MAINTENANCE OF A ROAD.

Unless the requisite funds are allowed for the maintenance of roads, it is wise to leave them alone, for money expended in forming

them, if they are afterwards to be neglected, is only thrown away. "Keeping up a road" is a very different thing from "repairing a road," though the two are often confounded. A due attention to the former will greatly lessen the necessity for the latter. The former keeps the road always in good condition; the latter makes it so only occasionally, after intervals of various length, during which it is continually deteriorating in a geometrical ratio, so that the better the state in which a road is kept, the less are the injuries to it, and, therefore, the less the expense of keeping it in this condition. The best time for making repairs to a road is the beginning of the monsoon, but on roads on which there is much traffic, it will not do to defer all repairs to that period, for not only would the traffic be much impeded, but the cost of the repairs would be much increased.

To "keep up a road" an establishment will be required, consisting of some carefully-trained head laborers, with Conicopolies or Measurers and Accountants, and European Overseers as Paymasters and general Superintendents. In the dry weather, carts and coolies will be employed under the Measurers, preparing and conveying the material for the repair of the road, and in rainy weather, the same parties will be engaged in repairing the road, turfing the side slopes, looking after the avenues, keeping the side drains clear, and filling up all holes in the surface as soon as they are formed. A road suffers little from a heavy load drawn upon it, provided the surface is smooth and regular; but when ruts or holes occur, the wheel sinks into them with all the increased momentum of the fall, and produces an effect that may be compared to that of a very heavy hammer falling upon the spot; and thus the hardest materials soon crush, and are ground to dust, while no such effect occurs on the road, while kept with a smooth and even surface. It is the duty of the establishment to see that all rules made for the preservation of the road are observed, that no encroachments are made on the road limits, that carts keep to their proper sides, and that all work is done in accordance with the general rules of the department.

From 50 to 100 Rupees a mile will be required annually for the repair of a road, on which the traffic does not exceed 50 carts a day. After that number is passed, it has been found that one cubic yard of broken stone per mile is required annually for each cart that passes over such mile daily. On the first 15 miles of the Western Trunk Road, from 1,000 to 1,500 carts pass each day. Between that and Vellore, the 85th mile, the traffic averages 800 a day. The establishment allowed for keeping in repair this, the most important road in the Presidency, is as follows, but additional coolies are required during the monsoon for making extensive repairs. The road is divided into divisions and districts, to simplify accounts and allow of regular and efficient superintendence. A district is 6 miles, having one Cart Conicopoly, one Quarry Conicopoly, and one Road Conicopoly, or *pygust*, as he is called, to distinguish him as a monthly paid servant from Conicopolies who draw only a percentage upon the amount of work they perform. Under the pygust, are too clever head laborers, ranking as Head and Assistant Head Coolies. To every 5 or 6 districts, there is one Assistant Overseer on Rupees 40 or 50 a month. Pygusts

get from 6 to 14 Rupees a month; Conicopolies, from 4 to 10; Head Coolies, 6½; Assistant Head Coolies, 5½—these two last each supplying a woman or boy to assist them. The Head Coolies work in a different mile every day, so as to insure a weekly inspection of each of them, execute the minor repairs during the dry season, water and tend the trees, prevent mischievous injury of the road and its avenues, prevent bandies stopping on it, and during the working season, they act as petty Maistries to direct the extra hands then employed, themselves working with them. The Overseer sees all the road at least once every ten days, and he regulates all the work, the number of coolies to be employed, &c. Every Maistry, Pygust and Conicopoly sends a short Monthly Abstract of the quantity and cost of all work performed in each mile, or at each quarry, or bridge, showing all the tools and materials in hand on date of despatch, with the pay or percentage which he has received for the month. The Overseer must determine in a great measure by his own observations and experience, as well as that of his subordinates, how to regulate and set about all the work of his division. His principal guides, in the absence of orders, are the estimate, the season, and the state of each particular portion of road, as regards subsoil, drainage, thickness and nature of the present crust, or of such as the allowance sanctioned for the division permits of his laying on. A Division Overseer can change the Conicopolies and Head Coolies from district to district, as he thinks fit, reporting the same on his Weekly Journal, but he must not move Pygusts or Maistries without referring the matter to the officer in charge of the line, with whom the general arrangement of districts and divisions rests. All persons in the monthly pay of the road department, must make themselves thoroughly acquainted with English figures, no other figures being allowed, and all Maistries, Pygusts and Lascars must be able to read the perambulator. All tools, not in the division store room, are in charge of either Maistries, Pygusts, or Conicopolies, and are kept in the district store room, being registered in the District Station Book and examined monthly by the Overseer, when he issues monthly pay. In cases of loss or wilful damage, the party who has caused the loss is to pay for the article, at its estimated value, and it is to be struck out of the list and the transaction duly recorded.

In every district, there should always be the following tools kept in good order:—

2 Mamooties,	2 Para Measures,
6 Pickaxes,	2 Yard Measures,
10 Crowbars,	2 Three-yard Measures,
2 Bill hooks,	1 Head Cooly's badge,
2 Road Levels,	1 Barrier.
10 Rammers,	

And besides these, there should be in every Division store

1 Table and Stool,	2 Trowels,
1 Cash-Box,	1 Hand-cart,
2 Parah Measures,	1 Barrow,
2 Nine-feet Rods,	4 Paint Brushes,
1 Twelve-feet Rod,	1 Pot of White Paint,
3 One-yard Measures,	1 Pot of Black Paint,
2 Fifty-feet Tapes,	1 Bottle of Linseed Oil,
1 Tin Water-level,	1 Rain Gauge.
1 Two-feet Carpenter's Rule,	

TRACING GHAUTS.

Before commencing the trace of a mountain pass or *ghaut*, the best attainable map of the country should be consulted, and a preliminary and careful inspection of the slopes of the range to be crossed will be necessary, with a view to ascertain the direction and extent of the ravines and water-courses, and the nature of the ground, whether it admits of being cut, or if it is too rocky and precipitous.

If the hills are extremely wooded, the operation becomes more difficult, but native foot-paths may often be found, and an inspection of these will show in some measure the nature of the ground, though not altogether, for they generally follow some spur of ground, and so fall into the lower part of the valley soon, and are very steep. They afford, however, useful hints, and after having fixed upon the valley, through which the proposed road should be led, it is advisable always to survey any old road or path which may be found in it: this laid down on paper, will be a good beginning for a rough map of the country, and prove a guide to the direction of the new pass.

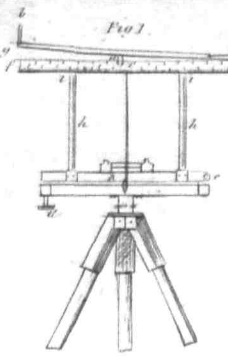
The slope at which the road is to be constructed, must now be decided upon; this will depend on the purpose for which the road is required, and something on safe halting places. It is not expedient that these should be far apart, but almost all hill ranges in India are feverish within certain limits, and except at particular seasons, people can seldom sleep within four miles of their base without danger. For quick traffic, which will probably be more thought of in future, the slope should in no part be steeper than 1 in 20, and if possible, should be less steep than that. Supposing the general minimum slope is 1 in 30, a great expense might be saved by making portions here and there, at a slope of 1 in 20, for a pair of bullocks could draw a full load for a few yards up a steep slope, though they could not do so for a greater distance. Having ascertained the height to be crossed, and assigned the maximum general rate of slope, multiply one by the other, and the minimum length is the result. Next, try to get a maximum length of hill, in the general direction of the proposed line, and the easiest possible ascent will be obtained.*

A valley or ravine extending far into the country to be ascended, or range to be crossed, affords a better hope of a good line of road, than following a spur and attempting to work it out by zigzags, and moreover has the advantage of every mile being so much in the ultimate direction while a zigzag is an expedient for gaining length with reference to the slope only and without reference to the ultimate progress, and should be avoided whenever the nature of the country affords the advantage above pointed out.

The instrument, with which the Periambaddy Ghaut was traced, was a Gunner's quadrant, with the spirit level changed to the other side of the arm, and the quadrant marked with a scale of natural tangents. This instrument was also used in tracing the Sumpagee Ghaut and was merely supported by a long stick held in the left hand. The slopes of the different parts of a ghaut may be easily measured in the following manner. Required the slope of DB

* See page 223.

Fig 1.



a Slide 1 inch high

bb Sights

c Shifting Bolt to retain the Plummet

d Milled headed leveling screw

ee Hinges

ef Bar divided into 8ths of Inches

g.e. Arm on hinge e.

h.h. Iron Supports 7 inches high to retain head having screws at i i to admit of the head being removed if requisite

k Horizontal Bar.

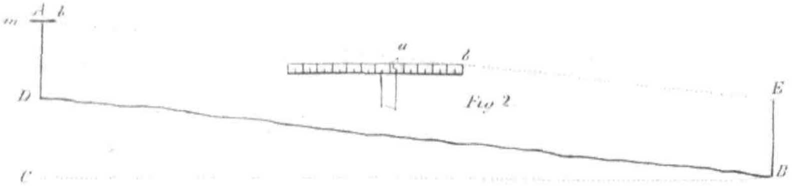


Fig 2.

Plan of Stand

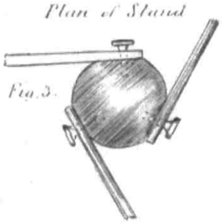


Fig. 3.

Elevation of Stand

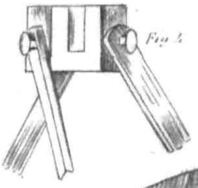


Fig 4.

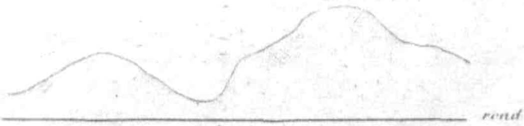
Fig 5

Dotted line shows the trace
The line the road

Fig 6.

The dotted line shows the road had it followed the trace, the shaded part shows the road as executed

Fig. 7.



Section

(Pl. XXVII, Fig. 2) or the proportion of DC the vertical to CB the base. AD and BE are equal staves, each about 4 feet long. The staff BE is to be held upright at the bottom of the slope and AD at the top; *mb* is a straight rule of 2 feet or 18 inches length accurately divided into half inches. It is to be fixed or held at right angles to the top of AD—that is, horizontally. A small rule of triangular section is then to be held across *mb*, in such position, that *a*, *b* and E may be seen in the same straight line. The number of half inches from *b* to *c* will then be the base of the slope to vertical one. For *ac* is one-half inch, and in the similar triangles *acb*, DCB.

$$ac \; : \; cb \; :: \; DC \; : \; CB$$

$$1 \text{ half inch} \; : \; x \text{ half inches} \; :: \; 1 \; : \; x$$

The instrument shown in Pl. XXVII, Fig. 1, is on the above principle, but has several additions, by means of which, greater accuracy is obtained. The description of the several parts in the Plate will explain the construction. The plummet will not be required when there is a spirit level, but it is intended to supply its place when wanting. A stand suited to this and other similar instruments, is shown in Figures 3 and 4. The instrument may be used with the hand alone or on a stand, except, however, for mere trial traces, it is better always to use the stand, and the greatest accuracy should be employed in laying off the slopes, to prevent the future annoyance and difficulty which irregular slopes occasion the Executive Officer, in converting the trace into a complete road, and which, without more superintendence than can commonly be given, leads to mistakes.

It is difficult to write generally on the other points to be attended to in tracing—viz., fixing the head and foot of a ghaut, the places to cross rivers and steamers, and when to change from one valley to another: some of these become fixed points, to which the road must be brought, and it requires considerable care to determine them to the best advantage, and no slight practise to work the slopes into them, without expedients or loss of ground.

Experience in executing a road will be found necessary, to enable the tracer to avoid a great many inconvenient errors, into which he will otherwise generally fall.

It is astonishing what may be done by varying the slope, but one foot, as from 1 in 20 to 1 in 19, or from 1 in 20 to 1 in 21, and it is useful to bear in mind, that in this manner, if the tracer comes suddenly upon a large rock, to avoid tunnelling through which, he must pass by either top or bottom, let him take his fresh station according to circumstances at either point, and then setting up his instrument, work back till he falls into his trace again. The variation of slope will be so slight, that it will require a quick eye to detect it, and the impediment will be passed without a zigzag.

In tracing the Periambaddy road, two of the fixed points were water, shed lines or saddles dividing vallies, in this case, but a few feet broad: it was necessary to cross them, to keep the proper direction of the road, and accordingly these points were worked from, the one down and the other up, the result, on a trial trace, was a slope varying from 1 in 12 to 1 in 15, and a long flat of 1,000 yards. When

the thick forest came to be partly cleared, and the shape of the ground could be better discovered, this was worked out at a slope of 1 in 16 and 1 in 18, for very short distances, and a heavy bank was raised with a bridge 5 yards high across the intermediate valley and river. The greater part of this was at a slope of 1 in 20 and 1 in 30, and the road having been carried higher and so nearer the heads of the ravines, is necessarily straighter, Fig. 5.

When subsidiary ravines are not too deep, and yet run a long way back, so that the road would have to skirt them, if traced in the usual manner, with continual slope, it may be better to carry the trial trace round them horizontally, because, when the jungle comes to be cleared, and the difficulties to be seen, the ravine may, perhaps, be crossed by a bridge, or embankment and drain, as deemed expedient. In open grass land, the difficulties are visible, a sight can be taken across at once at the regular slope, if that be determined for the direction of the road.

In the construction of mountain roads, it should be borne in mind, that as a general rule, the trace shows the centre of the road, but, to straighten the inner scarp, the high spurs are often cut down, and the hollows filled up, (Fig. 6) which, as it necessarily shortens the road, also renders it somewhat steeper than the original trace.

In tracing accurately, 2 pickets should be driven close together, at each sight (and the sights should be very short) one long, as an index, and the other, driven down till its head is on the required level.

The tracer may often make allowance for cutting through a narrow spur, instead of going round it, if he has length to spare.

An aneroid barometer will be found a great assistance to the tracer, in determining comparative heights, and its portability renders it much superior to the mountain barometer.

CHAPTER VIII.

WORKS OF IRRIGATION.

Irrigation is carried on in Southern India, by means of tanks, channels and wells; the last mentioned, however, are generally dug and kept in repair by private individuals, while the two former are looked after by Government.

Tanks.—Tanks are formed by throwing a bank across a piece of sloping ground; the drainage of the land above it then collects on the upper side. They vary in size from little reservoirs that hold barely sufficient water for raising a single crop, from three or four cawnies of land, to spacious lakes that are rarely dry, and yield to Government above half a lac of Rupees, as the tax on the fields cultivated by their means.* The more gentle the slope of the ground forming the bed of the tank, the greater will be the spread of the water, while the bank need be but of moderate height and section; but if the slope is steep, the bank must be high and strong, so that the depth of water in the tank may compensate for its little breadth. Deep tanks do not suffer the same loss from evaporation as others containing the same quantity of water, but showing a greater surface, and are on that account to be preferred. Some tanks are dependent for their supply entirely on local rain, and receive the drainage of the whole or a portion of the valley in which they are situated. Others are supplied by channels, cut from rivers, and when masonry dams (annicuts) are built across the rivers immediately below the channels, the supply is both more abundant and more certain. The inner slope of most large tanks is protected from the action of waves raised by high winds, by a revetment of loose stone. In districts where stone abounds, even the small tanks, and the exterior slopes of large ones have revetments of stone, and in other places, the growth of strong grasses and bushes should be encouraged with the same object. Great advantage would arise from careful planting both inside and outside tanks. Trees in banks are decidedly mischievous, high winds shaking them and bringing down the earth from about them, or even blowing them over and large masses of the bank with them. But palmyra or date trees, planted thickly along the foot of the rear slopes, and dates, baubool and a kind of mangrove (called in Teloogoo *cuddapa manoo*), planted at the foot of the bank inside tanks, strengthen them by preventing the earth from being washed too far

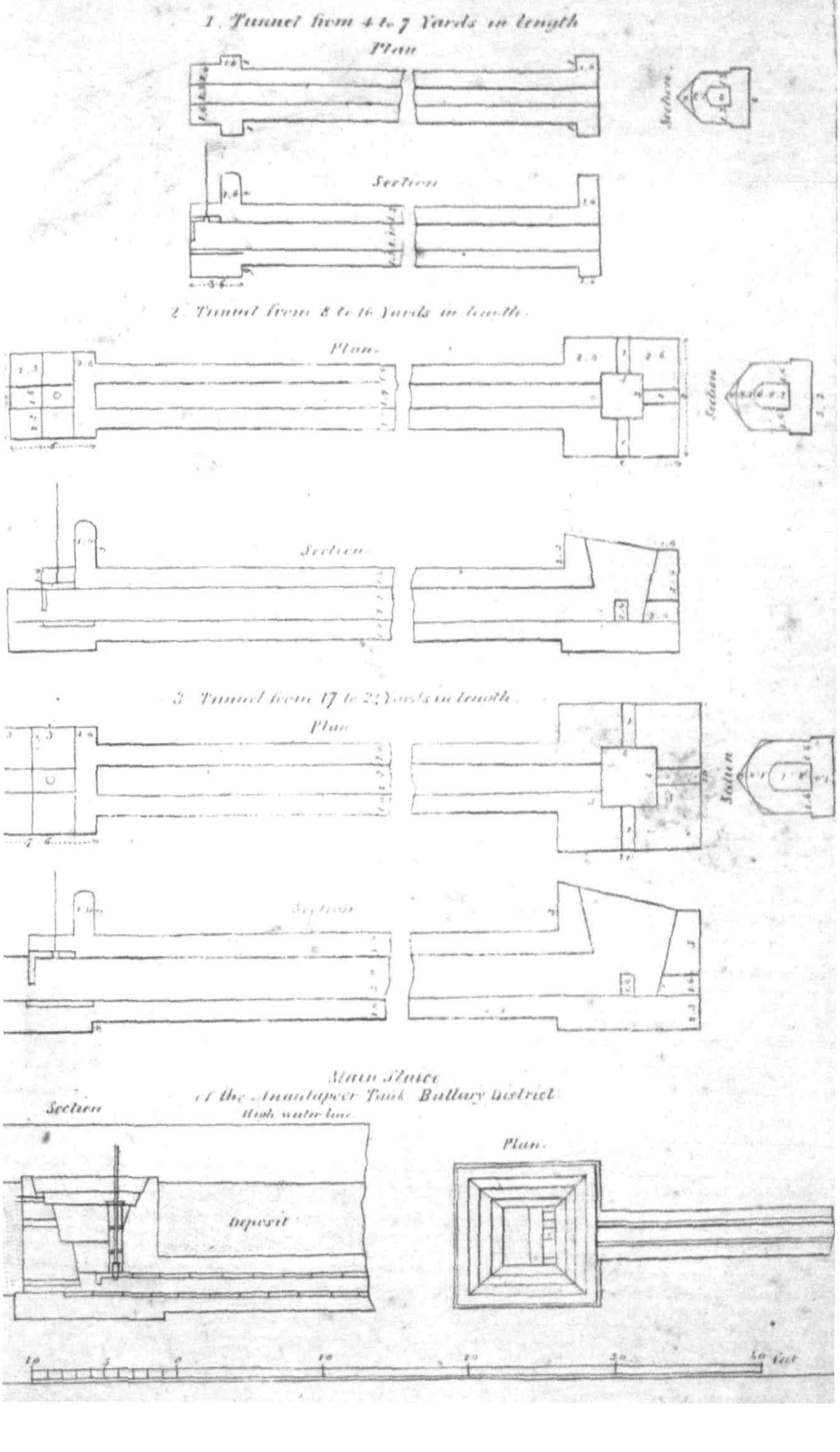
* Land to be cultivated with rice, requires daily as much water, as would cover it throughout to the depth of half an inch, or for raising a crop which takes 72 days' water—one yard. Thus, for a cawnie, or 6,400 square yards, a tank should contain 6,400 cubic yards of water, and a channel should supply for every cawnie to be irrigated by it $3\frac{1}{2}$? cubic yards, or allowing for wastage, 4 cubic yards per hour.

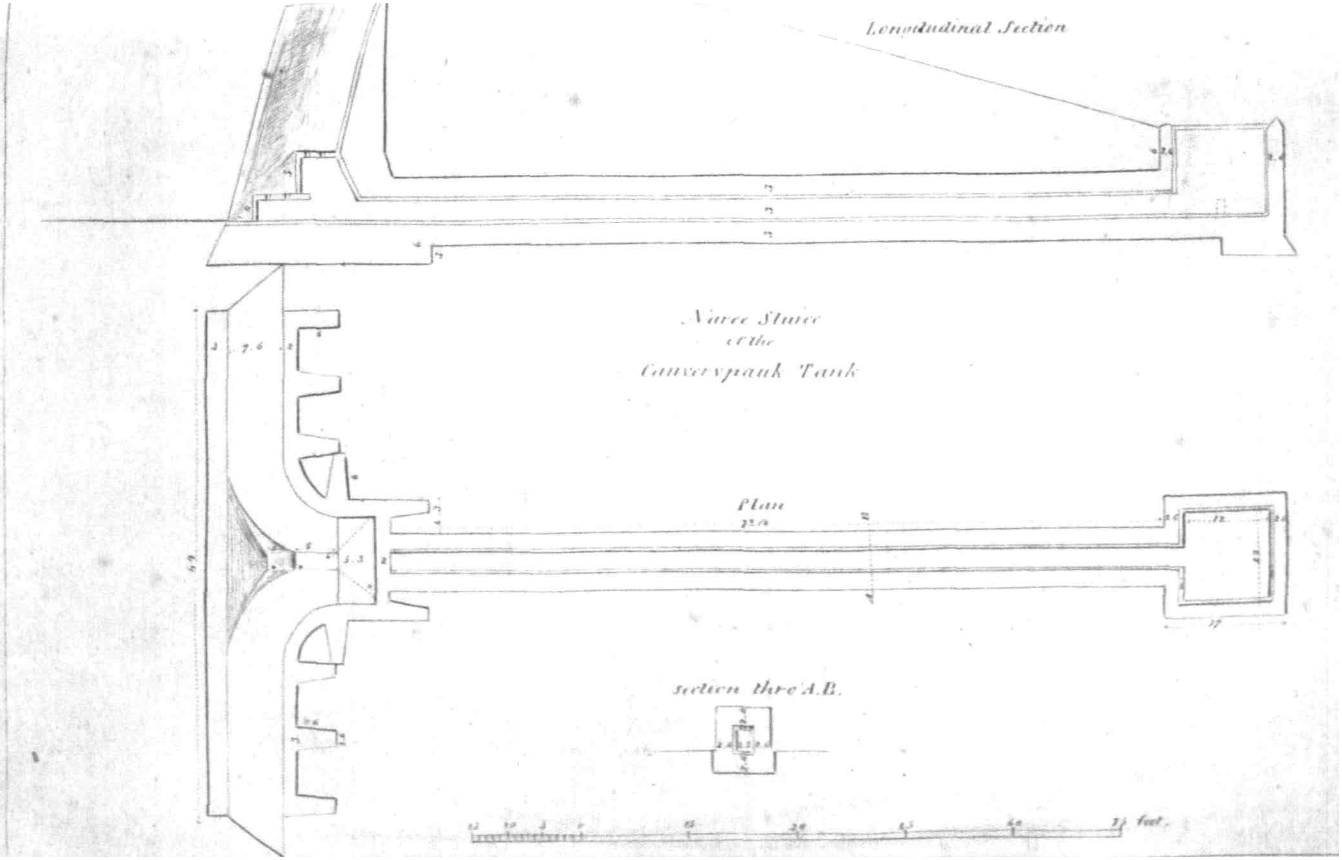
down, and protect them by breaking the waves. Numbers of the last named tree grow in the bed of the Veeranum tank in South Arcot, and are not damaged by the water rising high among their branches, and if such trees could be made to grow in similar localities (as doubtless they could if pains were taken) the expensive stone revetments of tanks might be dispensed with.

Tank Sluices.—To draw off the water from the tank, for the cultivation of the fields, sluices are built in the bank. If the tank be small, one is sufficient, built at the lowest levels; if large, several are necessary, placed at different levels. These sluices are merely tunnels of brick or stone work, arched at top, or covered with flat stones, terminating in a cistern behind the bank, and at the other end closed by stones, in which there are one or more holes, 3 inches in diameter, stopped up when necessary, either with a pieces of turf or a plug of wood attached to a long bamboo, to get at which, a man must in most cases go into the water, often having to swim. The formation of the head of the sluice, in one or more steps, is called the *piyal*, and is shown in Plate XXVIII. Most of the old native sluices had *gibbet stones*, or stones disposed in that form over the piyal, of which the one placed transversely is intended for a man to stand on, and has a hole made in it exactly over the orifice of the sluice, through which the bamboo passes that is attached to the plug with which the sluice is closed. These stones very much facilitate the opening and closing of the sluices: when they are wanting, a man must go under water to remove the plug with his hands, an operation not unattended with danger when the depth of water is at all considerable. When the side stones are of great length, there are two cross stones. The cistern in rear has its walls pierced with holes, which are sometimes at different levels, in order that the water may be taken to fields at various elevations. When cisterns are built in the front of tunnels, the object is to keep the entrance clear of mud and sand. Such cisterns are indispensable in tanks containing much deposit, and their walls are raised as the silt increases. This is shown in the two figures at the bottom of Plate XXVIII. Sluices not exceeding 25 yards in length are usually built according to the plans and sections in Plate XXVIII. Those in the banks of very large tanks are built according to special plans, of which Plate XXIX is an example. The tunnels of some of the old sluices are sufficiently capacious to allow of a man walking through them without stooping. They are closed in front by planks, sliding in grooves in the stones on each side. As the water subsides in the tank, the planks are one by one removed from the top and re-placed as it rises.

Calingulahs.—As more water often enters a tank than is required to fill it, provision has to be made for the passage of the surplus. If this were allowed to run out through a simple cut in the bank, it is evident that the force of the water would so much enlarge the opening, that it could not possibly be closed before the tank was entirely emptied. Hence, all tanks, except those of the smallest class, should have a portion of the bank formed of masonry, for the surplus water to flow over. The top of this part of the bank is much lower than the rest, but it can be raised to the height the water should be in the tank,

TANK SLUICES.




Longitudinal Section
Naree Sluice
of the
Cauverypauk Tank
Plan
section thro' A.B.
12 10 5 0 15 30 45 60 75 feet

after it has received its proper supply. These works are called *Calingulahs*; they consist generally of a wall of masonry, termed the *body*, in which upright stones are inserted at about three feet apart, with *wing-walls* on each side to prevent the bank being injured by the flow of the water, and behind, there is an *apron* with a *retaining wall* to it. The interstices between the upright stones are closed by a bank, formed with earth, turf, &c., which is removed when the supply of water is likely to prove too great, and renewed again afterwards. Small calingulahs have usually the top of the body apron and retaining wall at one level; in others there is often a considerable fall from the body to the retaining wall, in which case, the apron has to be made in one or more steps. If the fall does not exceed 3 feet, an apron of brick in chunam will answer, as the water only falls on it for a few hours once or twice in a year. If the fall is considerable, the apron must be covered with cut stone. When it is necessary to form the apron with rough stone, the blocks should be of large size, and they will have to be arranged in their places from time to time. The other parts of the calingulah may be either of brick or rubble masonry. There are still numbers of small and middling sized tanks, unprovided with calingulahs, the surplus water being allowed to run out over the high ground near the end of the bank. When the soil is rocky or very hard, it does not get much injured by the water passing over it, and the ryots find no difficulty in raising a small bank, to stop the outflow of the water when necessary. In selecting tanks to be furnished with calingulahs, preference should be given to those where the surplus water has to flow over light soil, which gets cut up, and puts the ryots to much trouble in closing the opening in time to retain a proper quantity of water in the tank. The best position for a calingulah is near the end of the bank, as the cost of construction will there be the least. When rock is met with in the tank bank, advantage should be taken of it for the foundation. The lower the body of the calingulah is placed, the less need be its length; but then the length of the upright stones must be increased and the labor of closing (in the way usually practised) will be very great. If the calingulah is placed at or near the level of the highest water of the tank, upright stones will not be required, but the length must be very great. Sometimes a piece of rock is met with, that answers perfectly as a calingulah, or as an auxiliary to it during very heavy rains.

In most large tanks, the water is brought from rivers by channels, and the quantity of supply may be regulated by a head sluice. In other cases, the dimensions of the calingulah should depend on the proportion that the tank bears to the surface of the land which drains into it.* Calculated on the supposition that the tank was full before the rain commenced, and that the fall was as heavy as any on record, the size of calingulahs should be much greater than of those now in

* The velocity of water issuing from an opening, such as a calingulah, depends upon the height of the surface of the water above the opening, measured from the surface of the water that has just escaped. It is found by multiplying the square root of that height by 5, and the height being in feet, the velocity will be in feet per second, thus—the height being 4½ feet, the velocity will be $5\sqrt{\frac{9}{2}} = 15\sqrt{\frac{1}{2}}$, this multiplied by the product of the height 4½ and the length L will give the discharge = L × 47¼ cubic feet per second, and 170,100 L the cubic feet per hour = 6,300 cubic yards, L being

existence. Practical experience will enable a person to determine the length with tolerable accuracy. An opening of 6 yards will, perhaps, be the least that it will be advisable to allow, and from that to 12 yards will do for small sized tanks. Second class tanks will require calingulahs of from 12 to 25 or 30 yards body. Some of the large tanks have calingulahs of very much greater length, but those within the dimensions above given, will be the most often required.

Calingulahs for ordinary situations, though varying in the length of their bodies, may yet agree in several respects, and it is desirable that they should do so. In Plate XXX, are the plan and section of a calingulah of 12 yards body of brick in chunam. The retaining wall is made a yard longer on each side, and the returns of the wing-walls are in a line with it. The returns of the wing-walls in front are in advance of the body by their breadth, and the splay in front is half a yard. The upright stones are placed 3 feet apart from centre to centre, and are 6 feet in length, 3 above the body, and the top of the stones is supposed to be at the highest water-level of the tank. The above relation of parts is generally applicable. The height of the wing-walls will depend on the class of the tank, but they should be at least half a yard above the top of the stones. The depth and breadth of the foundation will vary with the soil.

Fig. 2 is the section of a calingulah with the body raised 3 feet above the apron. Fig. 3 is the section of a calingulah with a second apron of brick in chunam, added in consequence of the channel in rear having been much deepened, by the force of the water, and rough stone not being procurable. Fig. 4 is the section of a calingulah, proposed to be placed in the breach in the bank of a ruined hill tank, there being no other position for it, and the failure of the tank being attributable to the want of a calingulah. Fig. 5 is the section of a calingulah, as lately reconstructed. The soil being very light, a deep channel had been formed in rear, and the apron had consequently to be made in steps. Surplus sluices (similar to the head sluice and bridge (Pl. XXXI) have been built in the banks of some tanks, in lieu of calingulahs. They are more easily opened and closed, allow the water to flow out with greater rapidity, and permit the escape of mud and sand (of the former not to any great extent) from the bed of the tank, but the common calingulah is much more frequently met with.

Channels.—Channels are cut from rivers, either for the purpose

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in feet. Now, supposing the tank to be full of water—to receive the drainage of one square mile—and the rain to fall at the rate of 3 inches an hour—the length of calingulah will be thus obtained.

A square mile = 1,760 X 1,760 yards = 3,097,600 square yards, and the cubic yards of rain will be 3,097,600 X $\frac{1}{12}$ = 258,133. Then we have

$$L\ 6{,}300 = 258{,}133$$

$$L = \frac{258{,}133}{6{,}300} = 40{\cdot}99 \text{ feet.}$$

The formula $V = \frac{2}{3}\sqrt{H} \times 5{\cdot}1$, where V stands for velocity and H for height, is given in several books, and is applicable to rectangular apertures of one or two feet in breadth, but it cannot be supposed that a large calingulah's discharge is reduced in the same degree. The formula $V = 5\sqrt{H}$, which has been used in the foregoing calculation, will be found more correct.

Calingulahs

Fig 1
Calingulah of 12 yards body

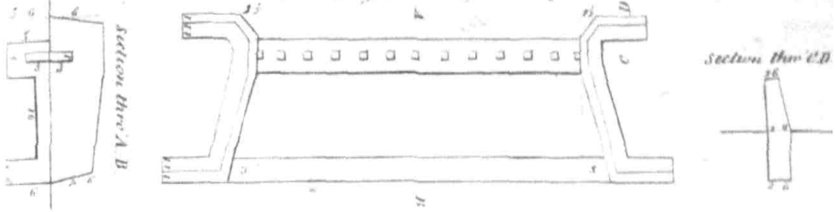


Fig. 2

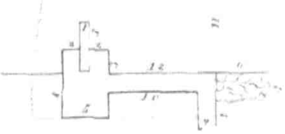


Fig 3

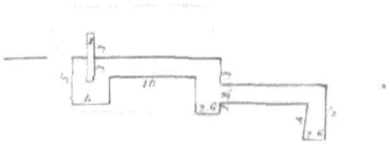


Fig 4

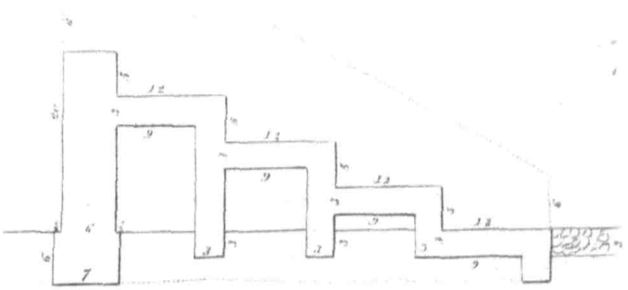
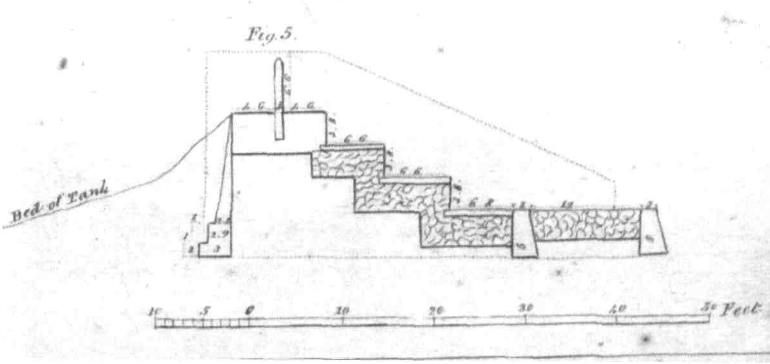
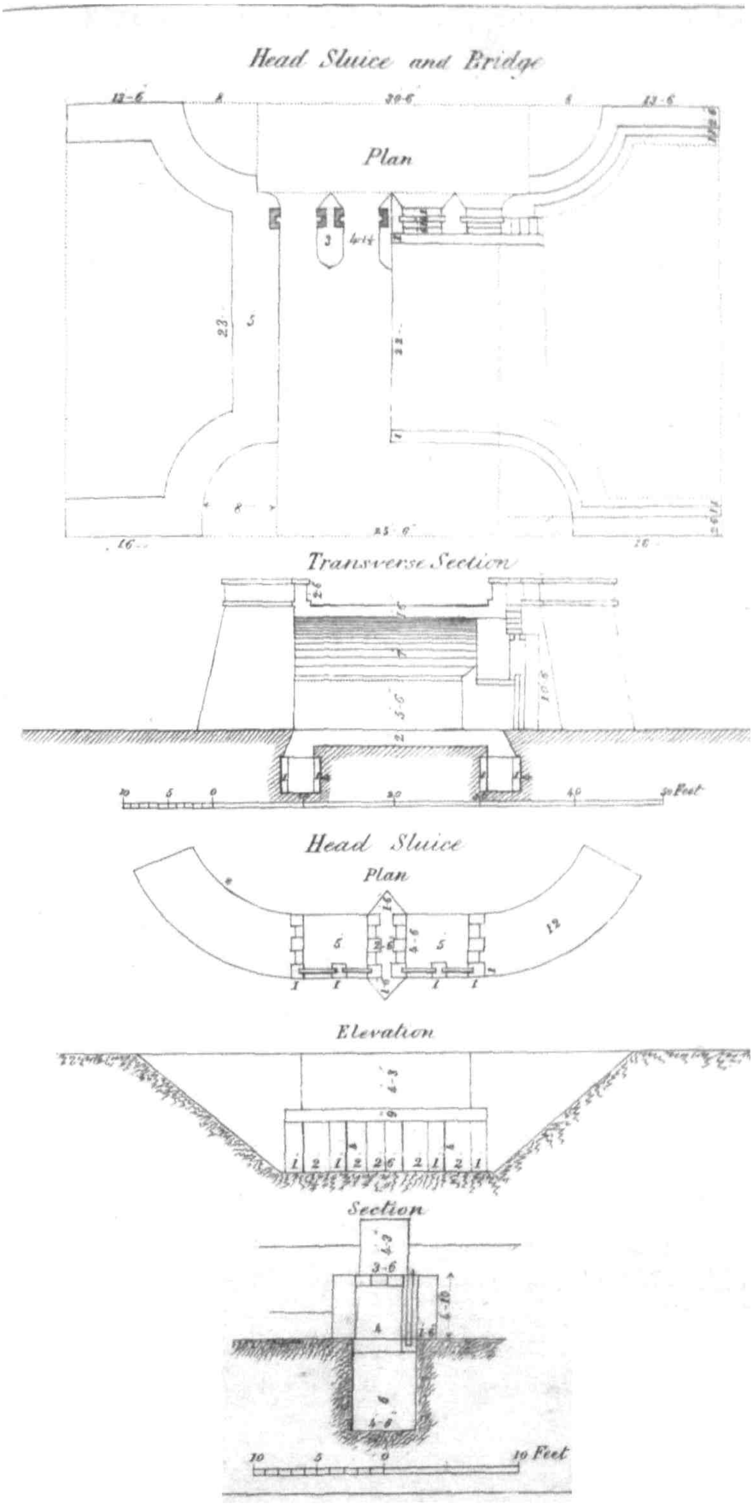


Fig. 5.




Head Sluice and Bridge
Plan
Transverse Section
Head Sluice
Plan
Elevation
Section
10 Feet

Plan of Part of the Foundation of the Vellaur Annicut & Bridge.

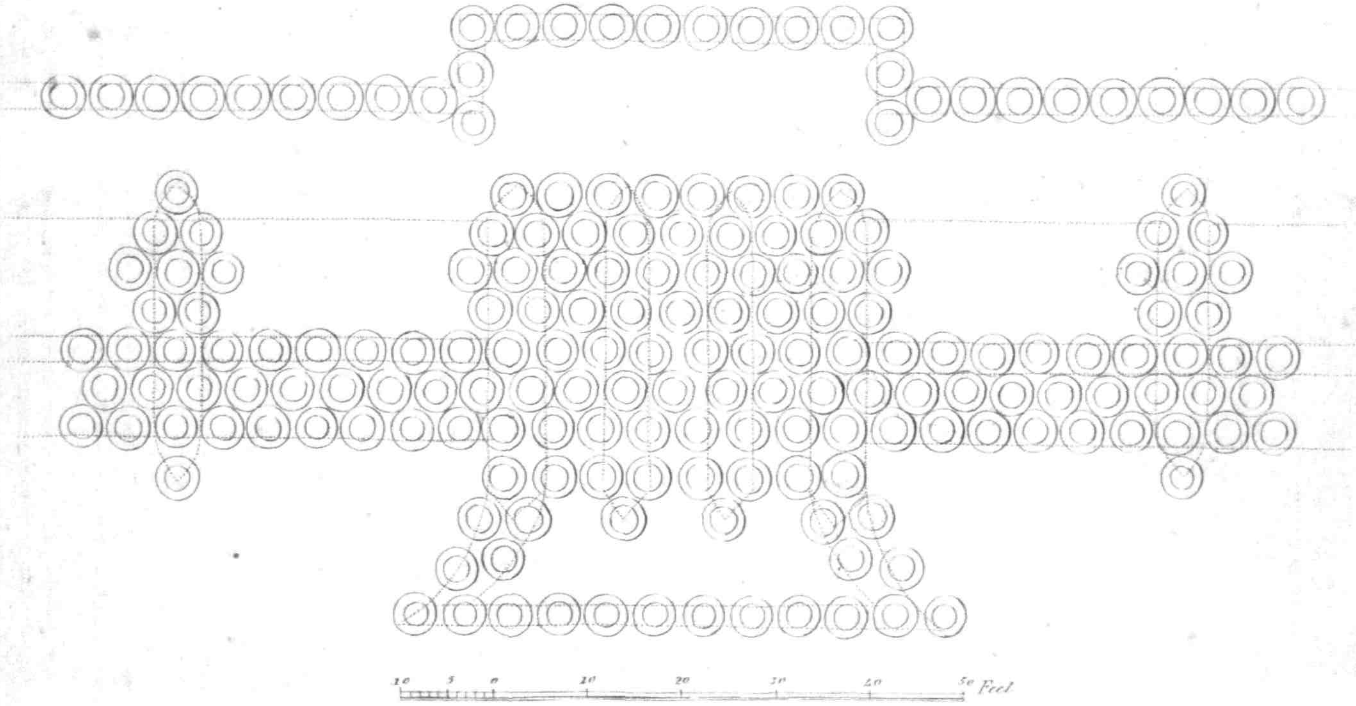


Fig. 4, is the section of one of the branches of the Godavery annicut. The construction is novel, the annicut being formed with sand cased with stone. Fig. 5, is another variety. The rise in the bed of the river before annicuts, which no sluices will altogether prevent, is here shown. Plate XXXIV, is a plan of a portion of the foundation of the Vellaur annicut and bridge, and shows the arrangement of the wells under one of the sluices, and under a pier and portion of the annicut on each side.

The above sketch comprises the principal kinds of irrigation works in *Southern India*. When the lands of a village are held directly from Government, the works are kept in repair at the expense of *Government*, but if *from* a *Zemindar or Shrotriemdar*, these *latter* are expected to keep them in repair. In cases where a portion only of a tank belongs to a Zemindar, the repairs are executed by Government, and a portion of the expense afterwards charged to the Zemindar.

In planning extensive repairs, or alterations, to works of irrigation, care must be taken that they are not of such a nature as to prove injurious to the ryots of an adjoining village. These will, however, be ready enough to come forward and protest against anything of the kind, and although their objections are often of the most frivolous nature, and raised solely from the absurd jealousy which the ryots of one village have of those of another, yet it is necessary that their statements should be carefully enquired into, as there may be truth in them.

REPAIRS OF IRRIGATION WORKS.

Repairs of Tanks.—The solidity of a tank bank, to bear a pressure of water, should depend on the depth, and be irrespective of the extent of water upheld by it. It is also of importance that the top of a bank should be sufficiently raised above the surface of the water, when the tank is full, for breaches seldom occur from the bank being too weak, but almost always from the water rising above the banks and flowing over them, or from the banks being washed away by the waves in stormy weather, and as the waves are larger in proportion to the depth and spread of water, the height of the bank should be increased accordingly. It is only within the last few years that any attempt has been made, in repairing banks, to make the top of a uniform width and height above the water. The consequence was, that tanks were being frequently breached from the weakness of the bank at one part, while three-quarters or more of its entire length was much stronger than there was any occasion for. An estimate for repairing a bank was made somewhat as follows. The Tahsildar or Maistry began by considering not what the state of the bank was, and what it should be, but how long it was since it was repaired, and how much revenue was connected with it. By such considerations he determined whether it should be repaired or not, and how much money should be granted. The money was then converted into so many cubic yards of earth, at such and such a price, and this was distributed into so many yards long, wide and high. When the estimate was sanctioned, the tank-diggers would be sent for, and told to dig a certain number of cubic yards, which they proceeded to do,

and being rarely furnished with a copy of the estimate, or other directions, they applied the earth to such parts of the bank, and in such manner, as they pleased. Their object being not to repair what needed repair, but to do such quantity of work as might entitle them to the payment they expected, and might not spoil the chance of their obtaining work at the same place on a future occasion.

With a view to introduce regularity in the preparation of estimates, and a better method of executing the repairs, the following rules were drawn up a few years ago. They have been adopted in some districts and with the best results.

Rules for repairing Tank Banks.—Tanks should be divided into three classes. First class—all large tanks whose breadth of water exceeds 300 yards and depth 3 yards: second class—all middling sized tanks, the breadth of water spread being under 300 yards and above 100 yards, the depth of water being from 1½ to 3 yards: third class—small tanks whose water spread is under 100 yards and depth from 1 to 1½ yards. In preparing an estimate for tank repairs, the first thing to be determined, is to which of the above three classes the tank in question properly belongs, for according to its class, will be the height and breadth of bund required. In all first class tanks, the top of the bund should be 2 yards above the highest water-mark, and the breadth at top 2 yards, with a slope of 1½ to 1. In all second class tanks, the top of the bund should be 1½ yards above the highest water-mark and 1½ yards broad, with a slope of 1½ to 1. In all third class tanks, the top of the bund should be 1 yard above the highest water-mark, and the breadth at top 1 yard, with a slope of 1½ to 1. Some soils will require a slope of 2 to 1, or even more, but generally 1½ to 1 will be quite sufficient. Some tanks of the first and second classes are narrow or shallow near the two ends of the bank; when this is the case, the ends of the bank may be of second and third class sections respectively. The banks of a few tanks in each district, which are of remarkable size, may be of larger section than the above: a breadth at top and height above the water of 4 yards will be sufficient for any tank. When a road passes over any tank bank, the breadth must then be sufficient for the traffic.

Having determined the class to which the tank belongs, the person making the estimate will commence his measurements from either end of the bund, taking care, however, to mention which end in his estimate, and note down in the field-book, the length of such parts as require repair, as well as those which are in good order, in regular succession; and while doing so, observe the average height of each *tak*, or length, above the highest water-mark, the breadth of the bund at top, and the height of the same above the paddy fields or ground in rear. In the column of remarks, the sluices, calingulahs, remarkable trees, &c., that will serve to distinguish the taks, ought to be noticed, and the state of repair of the masonry works, as also that of the turfing and revetment should be mentioned. In this column, the distance the earth has to be carried, and the nature of the soil are to be entered. These several items should be entered in the field-book according to the subjoined form.

Fig 1.

Second Class Tank

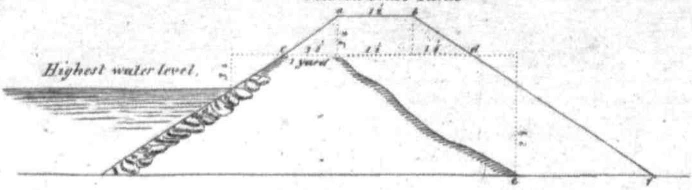


Fig. 2.

Fig 3.

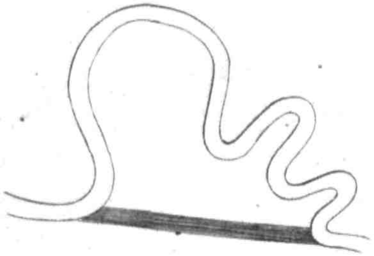


Fig: 4.

Fig 5

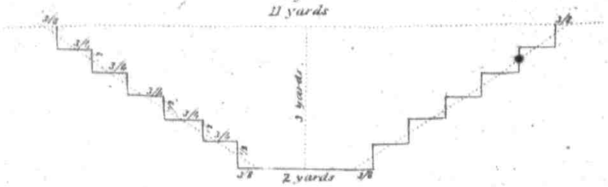


Fig 6

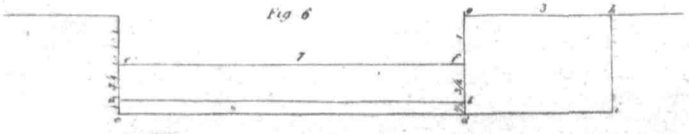


Fig. 7.

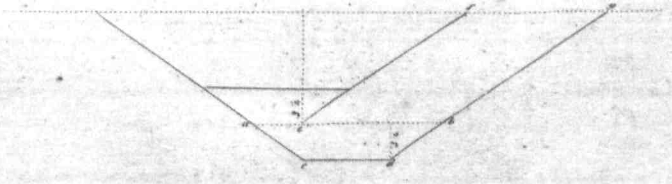


TABLE OF OBSERVATIONS.

1st September—Conjeveram Talook—Pootairy Tank.

Class of Tank.	Length of each Tak.	Height of present bund above high water-mark.	Breadth of bund at top in each Tak.	Height above the ground in rear in each tak.	REMARKS.
1	2	3	4	5	
Second Class.	100	$\frac{3}{4}$	1	$2\frac{1}{2}$	From West end.
	150	1	$\frac{3}{4}$	$2\frac{1}{2}$	
	200	$1\frac{1}{4}$	1	$2\frac{1}{4}$	Up to Pulla sluice—in good order.
	100	$1\frac{1}{2}$	1	2	
	50	$1\frac{1}{2}$	$1\frac{1}{2}$	2	Stone facing requires reconstruction $50 \times 1 \times \frac{1}{2}$.
	180	1	$\frac{1}{4}$	$2\frac{1}{4}$	

Example.—In the section (Pl. XXXV, *Fig.* 1), which has been drawn to correspond with the first entry in the above field-book, the height of the old bund above the high water-mark is $\frac{3}{4}$ yard, breadth of old bund at top 1 yard, height above the ground in rear $2\frac{1}{2}$ yards, length of tak 100 yards. The tank being second class, the proper height of the top of the bank above the water is $1\frac{1}{2}$ yards, and the additional height required is therefore $1\frac{1}{2} - \frac{3}{4} = \frac{3}{4}$ yard. The breadth at top being $1\frac{1}{2}$ yards and the slope on each side $1\frac{1}{2}$ to 1, the breadth at bottom for a height of $\frac{3}{4}$ will be $3\frac{3}{4}$ yards. The average breadth will therefore be $\frac{1\frac{1}{2} + 3\frac{3}{4}}{2} = 2\frac{5}{8}$. The breadth of the new additional bank at bottom will be $3\frac{3}{4} - 1 = 2\frac{3}{4}$ yards. The calculation will then be as follows:

$$100 \times \left\{ \begin{matrix} 2\frac{5}{8} \\ \text{average breadth} \end{matrix} \right\} \times \left\{ \begin{matrix} \frac{3}{4} \\ \text{height} \end{matrix} \right\} = 196\frac{7}{8}$$

for the upper portion above the old bank, viz., *a b d c*

$$100 \times \left\{ \begin{matrix} 2\frac{3}{4} \\ \text{breadth} \end{matrix} \right\} \times \left\{ \begin{matrix} 2\frac{1}{2} \\ \text{height} \end{matrix} \right\} = 687\frac{1}{2}$$

for strengthening the lower portion, viz., *e f d c*. The two products added together give the total earth-work required for the length of the tak 100 yards.

To form an estimate from the foregoing observations, the following tables will be found useful. If the tank is first class, No. 1 table is to

be used; if second class, No. 2 table; if third class, No. 3 table; and for very large tanks, No. 4 table is to be used.

TABLE 1. For first class Tanks.

Average height of bank above high water-mark.	To be raised.	Average breadth.	Thickness of new bank at bottom.
3	6	7	4
2			2
1 7/8	1/8	2 2/16	2 3/8
1 3/4	1/4	2 3/8	2 3/4
1 5/8	3/8	2 9/16	3 1/8
1 1/2	1/2	2 3/4	3 1/2
1 3/8	5/8	2 15/16	3 7/8
1 1/4	3/4	3 1/8	4 1/4
1 1/8	7/8	3 5/16	4 5/8
1	1	3 1/2	5
7/8	1 1/8	3 11/16	5 3/8
3/4	1 1/4	3 7/8	5 3/4
5/8	1 3/8	4 1/16	6 1/8
1/2	1 1/2	4 1/4	6 1/2
3/8	1 5/8	4 7/16	6 7/8
1/4	1 3/4	4 5/8	7 1/4
1/8	1 7/8	4 13/16	7 5/8
0	2	5	8

TABLE 2. For second class Tanks.

Average height of bank above high water-mark.	To be raised.	Average breadth.	Thickness of new bank at bottom.
3	6	7	4
1 1/2			1 1/2
1 3/8	1/8	1 11/16	1 7/8
1 1/4	1/4	1 7/8	2 1/4
1 1/8	3/8	2 1/16	2 5/8
1	1/2	2 1/4	3
7/8	5/8	2 7/16	3 3/8
3/4	3/4	2 5/8	3 3/4
5/8	7/8	2 13/16	4 1/8
1/2	1	3	4 1/2
3/8	1 1/8	3 3/16	4 7/8
1/4	1 1/4	3 3/8	5 1/4
1/8	1 3/8	3 9/16	5 5/8
0	1 1/2	3 3/4	6

TABLE 3. For third class Tanks.

Average height of bank above high water-mark.	To be raised.	Average breadth.	Thickness of new bank at bottom.
3	6	7	4
1			1
7/8	1/8	1 3/16	1 3/8
3/4	1/4	1 3/8	1 3/4
5/8	3/8	1 9/16	2 1/8
1/2	1/2	1 3/4	2 1/2
3/8	5/8	1 15/16	2 7/8
1/4	3/4	2 1/8	3 1/4
1/8	7/8	2 5/16	3 5/8
0	1	2 1/2	4

TABLE 4. For very large tanks.

Average height of bank above high water-mark.	To be raised.	Average breadth.	Thickness of new bank at bottom.
3	6	7	4
4	0		4
3 3/4	1/4	4 3/8	4 3/4
3 1/2	1/2	4 3/4	5 1/2
3 1/4	3/4	5 1/8	6 1/4
3	1	5 1/2	7
2 3/4	1 1/4	5 7/8	7 3/4
2 1/2	1 1/2	6 1/4	8 1/2
2 1/4	1 3/4	6 5/8	9 1/4
2	2	7	10
1 3/4	2 1/4	7 3/8	10 3/4
1 1/2	2 1/2	7 3/4	11 1/2
1 1/4	2 3/4	8 1/8	12 1/4
1	3	8 1/2	13
3/4	3 1/4	8 7/8	13 3/4
1/2	3 1/2	9 1/4	14 1/2
1/4	3 3/4	9 5/8	15 1/4
0	4	10	16

The numbers in column 6 of the foregoing tables are obtained by subtracting the numbers in column 3 from the proper height above the water of the top of the bank. The numbers in column 4 are obtained by adding three times the numbers in column 6 to the proper top width of the bank, and the numbers in column 7 by adding the numbers in column 4 to the proper width and taking half the sum. The method of using the tables is as follows. First, to find the additional height—look in column No. 3 of the table, answering to the class of tank to be estimated, for the number in column 3 of the observations, and in columns headed 6 and 7 of the table will be found, in a line with that number, two other numbers, which, if multiplied together and again by the number in column 2 of the observations, will give the cubic yards of raising required. 2ndly, to find the additional width to be given to the bund before it can be raised to the above required height. Subtract the number in column 4 of the observations from the number in column 4 of the table, on the same line with the foregoing, and the remainder will

be the average breadth, which, multiplied by the numbers in columns 2 and 5 of the observations, will give the cubic yards of widening required. 3rdly, add together these two products, viz., raising and widening, and their sum will be the total cubic yards in each tak, and the sum of all the taks will be the total of the estimate.

Example of an estimate prepared from the foregoing observations.

Class of Tank.	Raising.				Widening.				Total of Raising and Widening.	Remarks.
	2 L	7 B	6 H	Total C. Yards.	2 L	4-4 B	5 H	Total C. Yards.		
Second Class.	100	$2\frac{5}{8}$	$\frac{3}{4}$	196 14	100	$2\frac{3}{4}$	$2\frac{1}{2}$	687 8	884 6	From West End.
	150	$2\frac{1}{4}$	$\frac{1}{2}$	168 12	150	$2\frac{1}{4}$	$2\frac{1}{2}$	843 12	1,012 8	
	200	$1\frac{7}{8}$	$\frac{1}{4}$	93 12	200	$1\frac{1}{4}$	$2\frac{1}{4}$	562 8	656 4	Up to Pulla Sluice.
	100	...	...	...	100	$\frac{1}{2}$	2	100 0	100 0	
	50	...	...	...	50	...	...	...	...	Stone facing require reconstruction.
	180	$2\frac{1}{4}$	$\frac{1}{2}$	202 8	180	$2\frac{3}{4}$	$2\frac{1}{4}$	1,113 12	1,316 4	

3,969-6 cubic yards of earth at 10 pie per cubic yard ... ... Rs. 206-11-9

$50 \times 1 \times \frac{1}{2} = 25$ C. yards of reconstructing Stone facing at 3 Annas a yard 4-11-0

Total Rs... 211-6-9

The rules giving the numbers to fill up the columns will give = 0 for those parts of the bank which require no repair, as in the fourth and fifth taks of the example. When there are breaches in a tank bank, sufficient earth should be allowed in the estimate for filling up the holes in front and rear, made by the rush of water, to the natural level of the ground, and for raising the bank to the same height as in other places. It is not necessary to estimate for making these parts one or two yards higher than the rest, as is often done, the new earth will at first always occupy more space than the calculated contents of the breach.

Should an estimate made according to the rules here given, be too large, compared with the revenue derived from the tank, its amount may be diminished by assuming the high water-mark $\frac{1}{4}$ or $\frac{1}{2}$ a yard below what it really is. When the section of a tank bank is only a trifle less than it should be, it will be better not to repair it, as the small quantity of earth that would be thrown on the bank would not adhere to it properly.

When a tank has a stone revetment, the high water-mark may generally be seen on it, also on the dam stones and wing-walls of the

calingulah, sluice-stones, &c. The Maistry, in making enquiries on this point of the ryots, should be very particular, as they are in the habit of asserting that the tank receives a great deal more water than it really does. When the banks of large tanks require extensive repairs, it is a very good plan to take a longitudinal section of the bank with a levelling instrument, as the estimate can then be made with great accuracy, and if previous to the work being commenced, marks are set up showing the heights the bank is to be raised in several places, the new bank can then be made perfectly level at top throughout, but without such guides, this will never be the case.

Repairs to river and other embankments can be estimated according to the above rules. The proper time for the talook authorities to make estimates for tanks and channels is, when there is water in them. The Maistries should begin their duty so early, that every estimate may be completed by the end of the monsoon.

Method of executing the repairs.—After the estimate has been sanctioned, the tank bank should be repaired in the following way.

The lengths of the taks in the estimate (or a sufficient number of them) should be marked out, and the heights of the bank is to be raised in each tak fixed by pieces of stick, or heaps of earth, and sections made with bamboos and rope should be set up at intervals, so that the breadth of the bank at top and degree of slope may be clearly seen. The line of the bottom of the rear slope should be scored on the ground with a pickaxe or mamooty. The tank-diggers should commence the repairs by throwing the earth along this line, and while raising the bank, take care to preserve the proper slope, according to the section of the class of the tank. By working in this manner, the earth will be well trodden under foot and become firm, but if it be thrown on the top of the bank, and allowed to roll loosely down the sides (according to the usual practise) it cannot become solid, and a great part will be washed away in the first rains, besides which, the ryots will have great trouble in dressing the slopes, at the time of turfing them. Repairs should always commence at the end from which the estimate was made, or else from some fixed point, as a sluice, or calingulah, and each tak should be completed before another is begun, so that the Overseer or Maistry who inspects the work, while in progress, may be able to note, that so many yards in length of the bank, from a certain point, were completed on a certain day. At his next inspection, he has only to commence his measurements from that point; but if the repairs are going on at several points at once, then, at each inspection, all the pits have to be measured, for it is impossible to distinguish the new pits from those seen on former occasions, and thus a great deal of time is wasted. In filling breaches, the earth should be rammed daily, but the cross section need not be made greater there than at other parts of the bank. A favorite notion with natives is that a bank that has once been breached is always particularly liable to be breached again in the same spot, and there are few large tanks, in which, when the villagers get their own way, they do not bestow a part of the earth allowed for repairs upon the *maumool* breach, although the bank there is many times larger than at any other part.

The tank-diggers must not be suffered to make the pits, whence the earth is to be taken, where they please, but the pits must be marked out for them by the Maistry or Monegar. The practise of making an immense number of diminutive pits, entails an enormous amount of unnecessary labor on those who have to measure them, and the difficulty of calculation is much increased by the dimensions frequently containing fractional parts. Care must, therefore, be taken to mark out as large pits as possible, in order that they may be few in number. The lengths of the sides should be yards without fractions, and in ordinary cases, the depth exactly one yard. When the ground is very hard, pits may be made exactly half a yard or exactly a quarter of a yard deep, but the depth must on no occasion be $\frac{3}{16}$, $\frac{7}{16}$, or $\frac{15}{16}$ of a yard. It often happens that ground immediately in rear of a bank, especially near the ends, is left uncultivated, merely from being a little too high to be reached by the water from the sluices. When this is the case, broad shallow pits $\frac{1}{2}$ or $\frac{1}{4}$ of a yard in depth, may be dug in these parts, and by so doing, the necessary amount of earth will be obtained, and at the same time, the extent of cultivation will be permanently enlarged. It was formerly the custom to dig all the pits in the bed of the tank, but the earth is now generally obtained from the ground in rear, where it is of a better description, and can be had at times when the water in the tank would not allow of its being taken from the inside. When good earth can be obtained from the bed of the tank, pits should not be dug in the fields, which are thereby much injured, except under the circumstances above alluded to.

At the commencement of the rainy season, the slopes should be covered with turfs, cut from clayey soil; palmyras and date trees may be planted at the foot of the rare slope, and the front slope, in the event of there being no stone facing, should be protected by strong grasses, such as naaul, koorkay, tashun cheddy, &c. The tops of all tank banks, which do not consist of hard soil, may be gravelled.

Stone facing.—The object of stone facing or revetments to tanks is more to protect the bank from the action of the water within the tanks, when agitated by high winds, and from injury from the rains, than to support the earth, or increase the resistance of the bank against the pressure of the water. The stones are usually applied in a single layer, and vary in size according to the height and size of the bank. The largest stones are placed at the bottom, and the foundation row should be sunk 9 or 12 inches in the solid earth, to prevent the work from being undermined. In some districts, where stones are plentiful and cheap, the revetment consists of two or more layers of stones at bottom with one layer of large stones at top backed by one of smaller dimensions. In building revetments, after the first course of stones is laid, the earth should be filled in behind to the height of the stones and well rammed; the second and following courses should be laid in the same manner. The stones should be well fitted together, and the crevices stopped with smaller pieces. It is of importance that the earth behind the stones should be well rammed, or it will be giving way, causing the stones to slip, and in a short time, the revetment will have to be re-built. The usual slope is $1\frac{1}{2}$ to 1, but a slope of at least 2 to 1 would be better, and the back of

all revetments should, if possible, be filled in with broken stone or gravel at least one-eighth of a yard thick.

Measurement of Earth-work.—The simplest and most correct method of ascertaining the quantity of earth to be paid for, is to take the cubic contents of the pits that have been dug. An objection to pit measurement is that the tank-diggers often dig the pits in uneven ground, or even trim the edges of pits of former years, and show them as new. This objection may be removed by adopting the plan already recommended, viz., marking out pits before the repairs are commenced, and not leaving it to the tank-diggers to dig them where they please. The frauds of tank-diggers have been much exaggerated. The truth is, they have lost much more from short measurement by the Revenue servants (who, to save themselves from the consequences of subsequent measurement by the Engineer department, keep on the safe side) than they have gained by all the simple contrivances they have for cheating the Circar. It will be useful, however, to have some check on this mode of measurement. Now tanks repaired according to the rules already given, have a check in themselves; for, if the inspecting officer sees that the top of the bank is throughout the proper width and height above the highest water-mark, with proper slopes, then it is evident that (supposing the estimate has been made correctly) that the proper amount of earth-work has been done. Hence, should the tank have received water, and the pits be all covered, so that their measurement is impossible, the correctness of the village accounts may be judged of by measuring the bank, but if possible, the tank should be visited before it receives water so that the pits may be measured.

Bank measurement should be looked upon as a check, and should not determine the amount to be paid to the tank-diggers, for it will not give the true amount. First, in case the estimate was not correct when it was made, second, in case any alteration took place in the state of the bank, between the time when the estimate was made and the execution of the work, or between the completion of the work and the measurement of it. The first case is one that happens very frequently, although the rules, if followed, will enable any person who understands them to make a sufficiently correct estimate, yet its degree of accuracy will depend upon the number of sections taken of the bank to be repaired; and if the bank be very irregular, there is a liability to error from the use of averages, and from not adopting the prismoidal formula in calculating solid contents.* The error thus arising would seldom be of sufficient magnitude to be important in an estimate, but it may be sufficient to vitiate calculations of work to be paid for. If the heights and widths of one portion of raised bank differ from those of another, according to the usual practise, an arithmetical mean is struck between the heights, and another between the widths, and the averages so obtained are then multiplied together and their product by the length, to obtain the number of cubic yards—which process is mathematically wrong. But unless the heights and widths varied a good deal, the error would not rech 10 per cent.,

* See Note—page 127.

which, as already remarked, would signify little in an estimate, but would be no trifle to the laborer, who would receive 90 Rupees for 100 Rupees of work done. Another advantage of pit measurement over bank measurement is, that the calculation of the former is perfectly intelligible to the Wudders, that the coolies soon understand that a pit of a certain size will be paid for at a certain rate, whereas any calculation of bank measurement is much more difficult. It is, of course, of great importance that the people who do the work should be able to judge whether they are paid correctly according to the tasks they have executed.

In measuring pits, all fractional parts should be rejected; thus, a pit that is actually $60\frac{5}{16} \times 4\frac{3}{16} \times 1\frac{1}{16}$ should be measured as $60 \times 4 \times 1$. If the tank-diggers have received previous warning on this point, there will be no hardship in the regulation.

The repairs cannot be considered completely finished, until the slopes are turfed. The turfing should be done at the very commencement of the monsoon, or earlier, if good turf can be procured.

Although the *quantity* of work executed may be correct, the *quality* may be very bad. Notice should be taken of all those parts of the bank which are not of the proper section, or which have not been repaired according to the instructions here given.

Repairs of Calingulahs, Sluices, &c.—*No particular rules can be* given for the repair of the various masonry works connected with banks and channels, such as calingulahs, aqueducts, &c., but the sluices in the banks of tanks, when requiring reconstruction, are usually built according to the plans in Plate XXVIII, which are also followed when additional sluices are necessary.

The only measurement required to be taken is the full breadth of the bank at bottom, at the place where it is proposed to build the sluice: this will be the length of the tunnel, but which may, in some cases, be made rather more. If the bank be not in good order, then the breadth it will be at bottom, after being repaired must be taken. The estimate may be expeditiously made with the assistance of the following table:—

Length of tunnel in yards.	Cubic yards of brick-work.	No. of stones.	Length of tunnel in yards.	Cubic yards of brick-work.	No. of stones.	Length of tunnel in yards.	Cubic yards of brick work.	No. of Stones.
4	$11\frac{11}{27}$	2	8	$37\frac{3}{4}$	3	17	77	3
5	$12\frac{24}{27}$	2	9	40	3	18	$79\frac{1}{2}$	3
6	$14\frac{10}{27}$	2	10	$42\frac{1}{4}$	3	19	82	3
7	$15\frac{23}{27}$	2	11	$44\frac{1}{2}$	3	20	$84\frac{1}{2}$	3
			12	$46\frac{3}{4}$	3	21	87	3
			13	49	3	22	$89\frac{1}{2}$	3
			14	$51\frac{1}{4}$	3	23	92	3
			15	$53\frac{1}{2}$	3	24	$94\frac{1}{2}$	3
			16	$55\frac{3}{4}$	3	25	97	3

The above number of stones is exclusive of *gibbet stones.* Cut stone, when found in the top and sides of old sluices, may again be made use of, and the cost of reconstruction will thus be diminished. Sluices in the banks of very large tanks are built according to special plants. It sometimes happens that tanks that contain but little water, have banks of large section. In such cases, if the standard plan were followed, a disproportionate expense would be incurred in building or reconstructing the sluice, it will, therefore, be better to adopt the plan and dimensions of the smaller sized sluices in all parts, except the *length* of the tunnel, which must, of course, depend on the breadth of the bank at bottom.

In order that masonry works and repairs may be well executed, it is necessary that they be commenced at a proper time, for it must be borne in mind, that in the early part of the working season, fine weather may always be reckoned upon, but towards the latter end, there are frequently heavy showers, which impede the progress of the work. Masonry works should be commenced in time to allow of their being dry before the monsoon: the materials should be of the best description, of the size previously mentioned and made in the way already described. The plans and estimates furnished by the Civil Engineer's Department, should be strictly followed, but when the work is in progress, should the Tahsildar or Maistry fancy that he can see an error, or suggest an improvement, he should at once communicate with the Civil Engineer's Department, and his representations will always meet with attention, but without such previous reference, alterations should not be made.

Repairs and improvements of channels.—There is a proper width for every channel. This proper width must be known to the person who estimates for clearing it. Many old channels are in some parts wider than they need be. The width of all channels should depend upon the extent and position of the land watered. Generally from the head to the irrigation fields, a channel should have the same width. After it has thrown off branches, the width of the main channel may be reduced in proportion. To lands that are low, the water will run quickly, and a narrow channel will suffice: to those on high levels, the water will run slowly, and the channel must be wide or deep, but changes must not be made in existing channels without proof of their necessity. It is necessary to estimate for widening those parts only, that fall short of the proper width. In widening old channels, they may generally be improved by straightening them at the same time. This is to be done by digging away the projecting corners at the bends (Pl. XXXV, Fig. 2), and must be attended to in making the estimate, and marking out the work before it is done.

Some old channels are so extremely crooked, that it will be found cheaper to cut a new line than to clear out the old course, (Pl. XXXV, Figs. 3 and 4,) and by doing so, the channel is permanently improved.

When soil has accumulated and mounds formed in a channel, water from the river will not reach the tank or fields. The Maistry should carefully observe where the obstructions are, and must mark on a rod the proper depth for the water, and in the wet season, or when the water is running, placing the rod upright on the bed of the channel, in the

water here and there, he must take notice how much of the rod appears between the surface of the water and the mark which he made on it, and the difference will show how much must be dug out in each place. If the water is deep enough, or more than enough, he will easily find out in the above manner. In those parts where the channel must be deepened, the depth and width should be measured in two or three spots and the average taken.

It is not necessary that the depth of the channel should remain exactly the same through the whole length; the depth in different parts more than 800 yards from one another, may vary according to the rapidity of the water, being less where the water flows quickly and greater where its motion is slow.

The bed of the channel ought to slope regularly from the bed of the supplying stream or river to the surface of the fields to be irrigated: old channels are generally deeper than necessary here and there. The excavation should be made only to the necessary depth. The Maistry must distinctly mark out the portions that are to be dug away to widen the channel, and also he must have small holes made for marks in the middle of the channel which will show the depth ascertained from his observations to be necessary, and will serve as guides for doing the work.

In those parts of a channel that have been enlarged, portions of the bank (*thundakurrahs*) a quarter of a yard broad must be left at regular intervals in order to serve for measurement of the work. These must afterwards be cleared away.

When a channel is dug more than half a yard deep, every successive half yard of depth must be kept less wide by three-quarters of a yard on each side, so as to allow for a proper slope to the sides: (Pl. XXXV, Fig. 5.)

The banks of the channels should be, if possible, 10 yards from the edges of the channels themselves. The banks of channels need not be made more than one yard high above the surface of the water when full. Mud and sand dug out from the channels if thrown up in high banks near the edge are washed by rain back into the bed. The high and steep banks are difficult to climb, and increased labor and expense are occasioned. Therefore, the mud and sand should be carried in baskets (not merely thrown out with the mamooties) and after the proper height (viz., one yard) of bank has been completed, the remaining mud, &c., should be spread out behind the old bank, so as not to fall back into the channel, or thrown in separate heaps, leaving paths so that the people may pass between and throw the earth behind the heaps. If the channel pass by any villages, the earth dug from it should be formed into a broad bank, with regular slopes and level at top, so as to serve for a road at all seasons. If the ground slope towards the channel, a check drain should be dug parallel to it, to save the sides from being injured in wet weather.

The estimate for clearing out a channel may be made thus. Having decided on the depth and width which the water in the channel ought to have in every part, it must be examined as already explained. The Maistry should note, first, the length of each tak; 2nd, the width of the surface of the water at the time of the observations; 3rd, the depth of the water; 4th, the height of the level ground

above the surface of the water. These several items should be entered in the field-book in the subjoined form.

TABLE OF OBSERVATIONS.

Proper Dimensions of Channel.	Length of each Tak.	Width of the surface of the water.	Depth of the water.	Height of the surface of the above water.	REMARKS.
1	2	3	4	5	
Width 10 yards. Depth of water 1 yard.	100	7	¾	1	From head of channel.
	200	8	½	1¼	
	100	7½	1	1¼	
	100	11	¼	1½	To Calingulah. Apron requires repair 4′ × 5′ × 2′ brick in chunam.

The way to make an estimate from the foregoing table of observations is as follows. First, to find the deepening required. Subtract the number in column 4 of the observations from the proper depth, and multiply the remainder by the numbers in columns 2 and 3 for the cubic yards of deepening; 2ndly, to find the additional width. Subtract the number in column 3 of the observations from the proper width, and multiply the remainder by the number in column 5 added to the proper depth, and also by the number in column 2, for the cubic yards of widening; 3rdly, add together these two products, viz., deepening and widening, and their sum will be the total cubic yards in each tak, and the sum of all the taks will be the total of the estimate.

Estimate prepared from the foregoing observations.

Proper size of Channel.	DEEPENING. 2 L	3 B	4 D	Total Cubic yards.	WIDENING. 2 L	3 B	5 D	Total Cubic yards.	Total of deepening and widening.	REMARKS.
Width 10 yards. Depth of water 1 yard.	100	7	¼	175	100	3	2	600	775	From head of Channel.
	200	8	½	800	200	2	2¼	900	1700	
	100	7½	0	0	100	2½	2¼	562-8	562-8	
	100	11	¾	825	100	0	2½	0	825	Up to Calingulah.

Total Cubic yards 3862-8 of

Earth-work, at 1 anna per C. yard	Rs.	241	6	6
40 C. feet of brick-work in chunam, at Rs. 2-8 per C. yard.	„	3	11	3
	Total Rs...	245	1	9

By referring to Fig. 6, Plate XXXV, which has been drawn to correspond with the first tak of the above estimate, it will be seen that the rules will give a true result only when the sides of the channel are vertical, or nearly so. When the banks are sloping, the rules for repairing tank banks may be followed; similar measurements will have to be taken, the raising of the bank corresponding with the deepening of the channel: see Fig. 7. Sometimes, however, a channel will be found so irregular, that it will be necessary to take cross sections at intervals, and calculate the widening and deepening required from those sections without reference to any rules.

An estimate may be prepared with great care and exactness, yet the repairs will be executed in a very unsatisfactory manner, unless the portions to be cut away, and the precise depths to be dug, are clearly marked out, and this is a point deserving of even more attention than the correct preparation of the estimate. Those who are provided with levelling instruments should always take a longitudinal section of the bed of any channel that requires clearing, as the precise depths to be dug can then be ascertained with great exactness, while merely guessing depths leads to much waste of money. No new channel should ever be cut without such section having been taken.

The total fall from end to end of the channel having been found, the proportionate fall for each place where the levelling staff was set up, can easily be calculated, which, compared with the corresponding number in the column of reduced levels, will show the amount of cutting (if any) that is required.

In the example of a field-book, at page 19, the observations may be supposed to have been taken along the bed of a channel, from the floor of the head sluice to the floor of the division sluice. The total distance is 1,440, and the total fall is 3 feet; the proper fall at the intermediate stations, so that the bed of the channel may have a uniform slope, will be found thus:

1440	:	240	::	3	:	·5
1440	:	480	::	3	:	1
1440	:	660	::	3	:	1·37
1440	:	1020	::	3	:	2·12

Now comparing these numbers with the corresponding ones in the column of reduced levels, it will be seen that at the end of the first tak, where there is rise of ·5 there should be a fall of ·5, consequently the depth of cutting required there, is $\cdot5 + \cdot5 = 1$ foot. At the second station, there should be a fall of 1 foot, while there is a rise of 1·5 feet—the cutting required will, therefore, be $1\cdot5 + 1 = 2\cdot5$ feet. At the third station there is a fall of ·75, while there should be a fall of 1·37—the cutting there required will be $1\cdot37 - \cdot75 = \cdot62$ feet. At the fourth station no cutting is required.

In making estimates, the average between the depths required at the ends of each tak is multiplied by the average width and by the length.

Thus, in the first tak, where the cutting required at the beginning

is 0, and at the end 1 foot, the average, or 6 inches, would be entered *as the depth of cutting for that tak. This often leads to a great mistake* in the execution of the work, for the whole tak is cut the average depth, thus, leaving the bed of the channel parallel to the surface of the former bed, or of the ground, as the case may be. To prevent this, the Maistry should be furnished not only with a copy of the estimate, but with a section of the ground, in which the precise depth to be dug at different points is noted. In the above example, supposing that no levels had been taken, the estimate would probably have provided for clearing the first half of the channel to a depth of half a yard, and the next to a depth of one yard—that is, giving the greatest amount of cutting, where least was required.

Estimates for channels are made in yards and sixteenths; so, if the depths have been taken from a levelling staff graduated to feet, tenths, and hundredths, they must be converted into yards and sixteenths, as nearly as can be, for which the following table will be found useful.

Fractional parts of yards.	Decimal parts of yds. corresponding.	Decimal parts of ft. corresponding.
$\frac{1}{16}$	·0625	·1875
$\frac{2}{16}$	·125	·475
$\frac{3}{16}$	·1875	·5625
$\frac{4}{16}$	·2500	·75
$\frac{5}{16}$	·3125	·9375
$\frac{6}{16}$	·3750	1·125
$\frac{7}{16}$	·4375	1·3125
$\frac{8}{16}$	·5	1·5
$\frac{9}{16}$	·5625	1·6875
$\frac{10}{16}$	·625	1·875
$\frac{11}{16}$	·6875	2·0625
$\frac{12}{16}$	·7500	2·25
$\frac{13}{16}$	·8125	2·4375
$\frac{14}{16}$	·8750	2·625
$\frac{15}{16}$	·9375	2·8125

If the depth according to the levels should be 2·23 feet, then $\frac{12}{16}$, the nearest corresponding fraction of a yard, should be entered in the estimate—and so on.

When a new channel is to be dug, the centre line must first be scored on the ground, then half the top breadth must be set out at right angles to the line at places where a change of depth occurs ; two lines must then be drawn joining the points thus obtained in order to show

whence the earth is to be dug. Knowing the depth and bottom breadth, the top breadth will be obtained by adding three times the depth to the bottom breadth, if the slopes are to be 1½ to 1, but if the slopes are to be 1 to 1, then twice the depth, and if 2 to 1, then four times the depth must be added to the bottom breadth.

It will be easier and better to dig the channel in steps on each side, than with sloping sides. In order that the area of the section thus made may correspond with the area of the section having sloping sides, the first offset at the surface of the ground must be made inwards from the lines marking the top breadth, and must be equal to only half the breadth of the other steps. The channel thus made will have a greater bottom breadth and less top breadth than if cut the other way, but after it has been in use a short time, the sides will have a continued slope, as shown by the dotted line in Figure 5, and the top and bottom breadths will become what they should be.

After the line has been marked, a pit should be dug at the end of each tak of the estimate, of the full depth according to the levels, and of a proper section. The heads of spring channels should always be dug before the rest is commenced. The pits will serve as guides to the work-people during the Maistry's absence, and it will be seen by them whether the soil is of the same description as was anticipated. If rock or hard soil is met with, a report should be made at once to the Civil Engineer's Department, that the estimate may be revised, the line altered, or the work abandoned. From not taking the above precautions, it not unfrequently happens that channels are dug at much greater expense than they are worth, as it is impossible to tell, without examination, the nature of the soil they will have to be cut through, and in the case of spring channels, unless the head be dug first, to ascertain whether water will be met with at a higher level than the fields it is proposed to irrigate, the rest of the channel may be dug in vain.

Preservation of Irrigation Works.—All works of irrigation, unless periodically repaired, will go to ruin, but the necessity for the repairs would be of less frequent occurrence if the ryots took more care of them.

There can be no doubt, that more expense is incurred by Government, in repairing injuries to the different works of irrigation, that have been caused by negligence, and that a little forethought and care would have prevented, than in repairing injuries due to fair wear and tear, or that have been occasioned by storms.

Some of the causes (trifling though they may seem) may here be noticed, which lead to the destruction of these works, and a consequent heavy outlay for repairing them—and also the simple means to be adopted for their preservation.

A tank bank, once properly repaired, should not again require money to be expended on it, for at least five years: for, with a very little care on the part of the Monegar of the village, it will remain in good order for fully that period. The injury done by a single monsoon is usually confined to the displacement of the turfing here and there, and

a few gullies in the slopes; these, if left alone, become considerably enlarged by the rain in the following year, and at the end of the third monsoon, the bank is in want of a thorough repair.

The Monegar, accompanied by the ryots, should, at the commencement of every monsoon, go along the tank bank and have the turfing renewed wherever it may be required, and the slopes repaired in the places where they have been injured. A couple of days will be sufficient for the purpose, and the tank will be rendered secure for the season.

Holes in the apron of the Calingulah should at once be stopped, for, one or two stones having been removed by the dhobies or otherwise displaced, often leads to the entire destruction of the Calingulah. Serious injuries to the Calingulah, or tank bank should be reported to the Tahsildar, in time to allow of their being properly repaired. Calingulahs should never be kept tightly dammed up, or they cannot be opened quickly during heavy and sudden falls of rain, or when the tank unexpectedly receives a large supply of water from the bursting of one immediately above it.

Grass and bushes should not be allowed to grow in the joints of masonry works, which are rapidly destroyed by them, as may be seen every day in the case of stone choultries and pagodas.

Breaches in the banks both of tanks and channels are often owing to their having been worn away in particular places, by the passage of men and cattle. The parts where banks are crossed by pathways should be regularly raised and repaired, before each monsoon, by the villagers. Breaches are also due to the practise of making narrow cuts in the bank, with perpendicular sides, for the passage of water, in lieu of the ordinary masonry sluices. These openings in the bank are closed at the approach of the monsoon, but usually in so hurried and careless a manner, that the new earth is soon carried away when the tank fills.

The slopes of tank banks are often much injured by cattle grazing on them. They should be kept off by planting thorns at the foot of the slopes, or by other means.

Channels should be regularly cleared every year by the ryots. The sand that would then have to be removed would not be more than to occupy them for a day or two, but if the channels are neglected for several years together, they get so choked up that they can only be cleared by Government at great cost.

Roads passing through paddy fields should always be kept at their full width, and on no account be used as channels for water, but ditches should be cut for the purpose on each side.

Masonry tunnels should be provided for all channels crossing roads, but when there is no tunnel, the channel should not be allowed to spread in a pool 20 or 30 yards broad over the road, but be kept within narrow boundaries.

Of the raised banks between paddy fields, one at least should be kept wide enough for the passage of a man or horse, so that the tank bank may be easy of access at all seasons.

APPENDIX.

BUILDING DATA.

The following building data have been selected from the Table of Rates for Madras. They will serve as a guide in preparing similar statements, but the Overseer is recommended not to pin his faith too closely to the details, but rather to observe carefully for himself. As prices must necessarily vary in every talook, and at different times even in the same talook, they are only given in the first items, to make the form complete.

Quantity.	WORKMEN AND MATERIALS.	Rate.			Per.	Amount.		
	Brick-work in Clay.	RS.	A.	P.		RS.	A.	P.
1,000	Wall bricks, 1st & 2nd sort....................	3	8	0	1,000	3	8	0
2½	Carts hire, for do.	0	10	0	each	1	9	0
1½	Cart load of clay	0	4	10	,,	0	7	3
1¼	Bricklayer	0	6	3	,,	0	7	9¾
¼	Man cooly	0	3	0	,,	0	0	9
1¾	Boys	0	1	10	,,	0	3	2½
	Sundries...	...	...	...	......	0	1	11⅓
	For 55* cubic feet...	...	...	...	......	6	5	11¾
	For 1 cubic foot†...	...	..	...	......	0	1	10¼
	Brick-work in Chunam.							
1,000	Wall bricks, 1st & 2nd sort....................	3	8	0	1,000	3	8	0
2½	Carts hire, for do.	0	10	0	each	1	9	0
6	Parahs of chunam................................	3	8	0	18	1	2	8
1¾	Cart load of River sand	0	6	10	each	0	11	11½
1	℔ of Jaggery‡	...	...	...	......	0	1	0½
1¾	Bricklayer	0	6	3	,,	0	10	11¼
¼	Man cooly	0	3	0	,,	0	0	9
4	Boys	0	1	10	,,	0	7	4
	Sundries..	...	...	...	......	0	1	0¾
	For 55 cubic feet...	...	...	...	......	8	4	11
	For 1 cubic foot...	...	...	...	......	0	2	5

* This is the number usually given, and if the bricks measure 9 X 4½ X 2¼ inches, it will be nearly correct. In the Madras data, 1,000 bricks are set down to 55 cubic feet—the bricks having of late dwindled down to about 8 X 4 X 1¾ inches, but no two brick-makers at Madras use moulds of precisely the same size. An experimental wall was lately built at Madras with bricks measuring 8¾ X 4¼ X 2¾, and 1,000 of them were found to occupy 80 cubic feet. They were also quite as well burned as the thin bricks. The quantity of chunam used was only 4½ parahs and of sand 8½ parahs.

† Add 1 pie per cubic foot for each story in height.

‡ The use of Jaggery is now prohibited in the D. P. W., as it is said to be useless.

Quantity.	WORKMEN AND MATERIALS.	Rate. RS.	Rate. A.	Rate. P.	Per.	Amount. RS.	Amount. A.	Amount. P.
	Flat Archwork in Chunam 6′ × 1¼′ × 1½′.							
215	Whole wall bricks	4	6	0	1,000	0	15	0⅝
25	Wall bricks, 3rd sort, for centring..........	2	5	4	,,	0	0	11¼
9-16th	Cart hire for do.	0	10	0	,,	0	5	7½
1¼	Parah of chunam........................	3	8	0	18	0	3	10⅔
¼	Cart load of River sand	0	6	10	each	0	1	8½
⅛	Cart load of sandy clay........................	0	4	10	,,	0	0	7¼
½	lb. of Jaggery	...	...	...	,,	0	0	6¼
⅞	Bricklayer........................	0	6	3	,,	0	5	5⅝
⅛	Man cooly	0	3	0	,,	0	0	4½
1½	Boys	0	1	10	,,	0	2	9
	Sundries	...	...	...	......	0	0	7
	For 11¼ cubic feet...	...	...	...	......	2	5	6
	For 1 cubic foot...	...	...	...	......	0	3	4
	Circular Archwork in Chunam 15′ × 1½′ × 1½′, (span of arch 8½ ft.) inclusive of centring.							
305	Arch bricks	5	0	0	1,000	1	8	4¾
305	Whole wall bricks........................	4	6	0	,,	1	5	4
150	Wall bricks, 3rd sort, for centring	2	5	4	,,	0	5	7¼
1⅞	Cart hire for do.	0	10	0	each	1	2	9
⅞	Cart load of River sand........................	0	6	10	,,	0	5	11¾
½	Cart load of sandy clay	0	4	10	,,	0	2	5
4	Parahs of chunam	3	8	0	18	0	12	5
2	lbs. of Jaggery	0	1	0½	lb.	0	2	1
3½	Bricklayers........................	0	6	3	each	1	5	10½
½	Man cooly........................	0	3	0	,,	0	1	6
7	Boys	0	1	10	,,	0	12	10
	Sundries	...	...	...	,,	0	1	7⅛
	For 33¾ cubic feet...	...	...	...	......	8	2	9⅜
	For 1 cubic foot...	...	...	...	......	0	3	10½
	Cornice work in Chunam 10′ × 1′ × ¾′.							
125	Whole wall bricks	4	6	0	1,000	0	8	9
5-16th	Cart hire for do.	0	10	0	each	0	3	1½
1	Parah of chunam........................	3	8	0	18	0	3	1⅓
¼	Cart load of River sand	0	6	10	each	0	1	8½
½	lb. of Jaggery	0	1	0½	lb.	0	0	6¼
¾	Bricklayer........................	0	6	3	each	0	4	8¼
¼	Man cooly	0	3	0	,,	0	0	9
1½	Boy........................	0	1	10	,,	0	2	9
	Sundries	...	...	...	......	0	0	2¾
	For 7½ cubic feet...	...	...	...	......	1	9	7½
	For 1 cubic foot...	...	...	...	......	0	3	5

Quantity.	WORKMEN AND MATERIALS.	Rate. RS.	A.	P.	Per.	Amount. RS.	A.	P.
	Column 12′ X 1½′ diam. including plastering.							
220	Bricks of 1½ ft. diam	17	8	0	1,000	3	13	7
25	Wall bricks, 1st & 2nd sort	3	8	0	„	0	1	4¾
1¼	Cart hire for do	0	10	0	each	0	12	6
3	Circular granite stones, 1¼′ diam............	0	8	0	„	1	8	0
6	Parahs of Chunam	3	8	0	18	1	2	8
1¼	Cart load of River sand......................	0	6	10	each	0	8	6½
1-16th	Cart load of white or Pit sand..............	1	11	0	„	0	1	8¼
4	lbs. of Jaggery	0	1	0½	lb	0	4	2
7½	Bricklayers	0	6	3	each	2	14	10½
1	Man cooly	0	3	0	„	0	3	0
1½	Woman cooly	0	2	2	„	0	3	3
7½	Boys	0	1	10	„	0	13	9
	Sundries	...	...	...	......	0	1	7
	For 12 Running feet...	...	...	...	......	12	9	0
	For 1 Running foot...	...	..	...	......	1	0	9
	Terracing with brick-on-edge, levelling course of wall bricks and 3″ thick brick-Jelly, 3 courses of flat tiles and plastering to ceiling and top of Terrace.							
2,000	Terrace bricks	2	8	0	1,000	5	0	0
1,200	Thick flat Tiles.................................	2	8	0	„	3	0	0
500	Thin or square Tiles...........................	2	8	0	„	1	4	0
200	Wall bricks, 1st & 2nd sort..................	3	8	0	„	0	11	2½
1½	Cart load of brick-Jelly........................	0	5	0	each	0	7	6
5¼	Cart hire for do.	0	10	0	„	3	4	6
18	Parahs of Chunam	3	8	0	18	3	8	0
3½	Carts load of River sand......................	0	6	10	each	1	7	11
⅛	Cart load of white sand.......................	1	11	0	„	0	3	4½
9	lbs. of Jaggery..	0	1	0½	lb	0	9	4½
10	Bricklayers	0	6	3	each	3	14	6
3	Men coolies	0	3	0	„	0	9	0
4	Women coolies...................................	0	2	2	„	0	8	8
20	Boys	0	1	10	„	2	4	8
	Sundries...	...	...	...	......	0	9	3½
	For 1 square or 100 sq. feet...	...	...	...	......	27	6	0
	Building Granite stone wall 10′ X 3′ X 2′.							
60	Cubic feet Granite stone wrought and delivered on the works	3	8	0	5 c. ft.	42	0	0
4	Parahs of Chunam	3	8	0	18	0	12	5⅓
¾	Cart load of River sand	0	6	10	each	0	5	1½
5	lbs. of Jaggery	0	1	0½	lb	0	3	1½
6	Bricklayers	0	6	3	each	2	5	6
9	Men coolies	0	3	0	„	1	11	0
4	Women...	0	2	2	„	0	8	8
3	Boys	0	1	10	„	0	5	6
	Sundries...	...	...	...	......	0	6	1¾
	For 60 cubic feet...	...	...	...	......	48	9	6
	For 1 cubic foot...	...	...	...	......	0	12	11⅓

Quantity.	WORKMEN AND MATERIALS.	Rate.			Per.	Amount.		
		RS.	A.	P.		RS.	A.	P.
	Building Laterite stone wall.							
100	Cubic feet Laterite wrought and delivered on the work	3	8	0	15 c. f	23	5	4
6	Parahs of Chunam	3	8	0	18	1	2	8
1½	Cart load of River sand	0	6	10	each	0	10	3
4	lbs. of Jaggery	0	1	½	lb	0	4	2
4½	Bricklayers	0	6	3	each	1	12	1½
4	Men coolies	0	3	0	,,	0	12	0
6	Boys	0	1	10	,,	0	11	0
	Sundries	...	...	...	......	0	4	5½
	For 100 cubic feet...	...	...	...	......	28	14	0
	For 1 cubic foot...	...	...	...	......	0	4	7½
	Facing with Granite stone in Chunam.							
120	Feet by 4 inches by 12 inches dressed 3 lines and delivered on the works and fitting up the same	3	8	0	12r. ft.	35	0	0
6	Parahs of Chunam	3	8	0	18	1	2	8
1½	Cart load of River sand	0	6	10	each	0	10	3
⅛	Cart load of brick-Jelly	0	5	0	,,	0	0	7½
⅛	Cart hire for do.	0	10	0	,,	0	1	3
4½	lbs. of Jaggery	0	1	0½	lb	0	4	8¼
8	Bricklayers	0	6	3	each	3	2	0
6	Men coolies	0	3	0	,,	1	2	0
6	Boys	0	1	10	,,	0	11	0
	Sundries	...	...	...	......	0	8	10¼
	For 100 sup. feet...	...	...	...	......	42	11	4
	For 1 sup. foot...	...	...	...	......	0	6	10
	Facing with Laterite stone in Chunam.							
120	Feet by 4 inches by 12 inches wrought and delivered on the works and fitting up the same	3	8	0	24 r. f.	17	8	0
6	Parahs of chunam	3	8	0	18	1	2	8
1½	Cart load of River sand	0	6	10	each	0	10	3
4½	lbs. of Jaggery	0	1	0½	lb	0	4	8¼
6	Bricklayers	0	6	3	each	2	5	6
4	Men coolies	0	3	0	,,	0	12	0
6	Boys	0	1	10	,,	0	11	0
	Sundries	...	...	...	...	0	6	10¾
	For 100 sup. feet...	...	...	...	...	23	13	0
	For 1 sup. foot...	..	...	...	...	0	3	9¾

Quantity.	WORKMEN AND MATERIALS.	Rate.			Per.	Amount.		
	Levelling course of Wall bricks under floors.	RS.	A.	P.		RS.	A.	P.
400	Wall bricks, 3rd sort	2	5	4	1,000	0	14	11
1	Cart hire for do.	0	10	0	each	0	10	0
⅜	Cart load of River sand	0	6	10	"	0	2	6¾
½	Bricklayer........................	0	6	3	"	0	3	1½
¾	Boy........................	0	1	10	"	0	1	4½
	Sundries	...	...	...	...	0	0	2¼
	For 100 sq. feet...	...	...	...	...	1	15	7
	Flooring with Brick-on-edge in chunam and pointing.							
800	Wall bricks, 1st & 2nd sort	3	8	0	1,000	2	12	9½
2	Cart hire for do.	0	10	0	each	1	4	0
5¼	Parahs of Chunam	3	8	0	18	1	0	4
1¼	Cart load of River sand........................	0	6	10	each	0	8	6½
2	lbs. of Jaggery	0	1	0½	lb.	0	2	1
2½	Bricklayers	0	6	3	each	0	15	7½
½	Man cooly	0	3	0	"	0	1	6
½	Woman cooly	0	2	2	"	0	1	1
4	Boys	0	1	10	"	0	7	4
	Sundries	...	...	...	...	0	0	8¾
	For 100 sq. feet...	...	...	...	...	7	6	0
	Flooring with 8 inches Square bricks.							
220	Square Bricks, 8 inches	17	8	0	1,000	4	0	4¾
11-16	Cart hire for do.	0	10	0	each	0	10	7½
3½	Parahs of Chunam	3	8	0	18	0	10	10¼
1	Cart load of River sand	0	6	10	each	0	6	10
2	lbs. of Jaggery	0	1	0½	lb.	0	2	1
1¾	Bricklayer........................	0	6	3	each	0	10	11¼
½	Man cooly	0	3	0	"	0	1	6
4½	Boys	0	1	10	"	0	8	3
	Sundries	...	...	...	...	0	0	6¼
	For 100 sq. feet...	...	...	...	...	7	4	0
	Paving with Laterite stone in chunam.							
100	Feet by 5 inches by 12 inches wrought and delivered on the work........................	...	...	...	...	10	0	0
⅛	Cart load of Brick-Jelly........................	0	5	0	each	0	0	7½
⅛	Cart hire for do.	0	10	0	"	0	1	3
6	Parahs of Chunam	3	8	0	18	1	2	8
1½	Cart load of River sand........................	0	6	10	each	0	10	3
3	lbs. of Jaggery	0	1	0½	lb.	0	3	1½
3½	Bricklayers	0	6	3	each	1	5	10½
2½	Men coolies	0	3	0	"	0	7	6
4	Boys	0	1	10	"	0	7	4
	Sundries	...	...	...	...	0	1	2½
	For 100 sq. feet...	...	...	...	...	14	7	10

Quantity.	WORKMEN AND MATERIALS.	Rate.			Per.	Amount.		
		RS.	A.	P.		RS.	A.	P.
	Asphalte floor ½ inch thick.							
266	lbs. of Asphalte	50	0	0	ton	5	15	0
¼	Cart load of River sand	0	8	0	each	0	2	0
10	Pollums Gingelly oil	0	8	0	viss	0	2	0
200	Sticks fire-wood	0	10	0	100	1	4	0
1	Bricklayer	0	8	0	each	0	8	0
1	Man cooly	0	4	0	,,	0	4	0
1	Boy	0	1	9	,,	0	1	9
⅜	Woman cooly	0	2	0	,,	0	0	9
	Sundries	...	...	...	...	0	2	6
	For 100 sq. feet..	...	...	...	...	8	8	0
	Sloping Roof with 3 courses of flat tiles and plastering 3 Coats chunam.							
1,200	Thick flat Tiles	2	8	0	1,000	3	0	0
500	Thin or square do.	2	8	0	,,	1	4	0
1 7-16	Cart hire for do.	0	10	0	each	0	14	4½
9	Parahs of Chunam	3	8	0	18	1	12	0
2 3-16	Cart load of River sand	0	6	10	each	0	14	11⅜
1-16	Cart load of white sand	1	11	0	,,	0	1	8¼
4½	lbs. of Jaggery	0	1	0½	lb.	0	4	8¼
4½	Bricklayers	0	6	3	each	1	12	1½
1⅝	Man cooly	0	3	0	,,	0	4	10½
2	Women coolies	0	2	2	,,	0	4	4
7½	Boys	0	1	10	,,	0	13	9
	Sundries	...	...	...	...	0	0	5⅝
	For 100 sq. feet...	...	...	...	...	11	7	3
	Sloping Roof with flat and pan tiles and chunam bars.							
500	Thin or square flat Tiles	2	8	0	1,000	1	4	0
1,500	Pan Tiles	2	11	1	,,	4	0	7½
1⅞	Cart hire for Tiles	0	10	0	each	1	2	9
3¾	Parahs of Chunam	3	8	0	18	0	11	8
1	Cart load of River sand	0	6	10	each	0	6	10
1½	lb. of Jaggery	0	1	0½	lb.	0	1	6¾
2	Bricklayers	0	6	3	each	0	12	6
1	Man cooly	0	3	0	,,	0	3	0
5	Boys	0	1	10	,,	0	9	2
	Sundries	...	...	...	...	0	0	10¾
	For 100 sq. feet...	...	...	...	...	9	5	0
	Plastering 1 Coat chunam to new walls.							
2	Parahs of Chunam	3	8	0	18	0	6	2½
½	Cart load of River sand	0	6	10	each	0	3	5
¾	lb. of Jaggery	0	1	0½	lb.	0	0	9⅜
1	Bricklayer	0	6	3	each	0	6	3
¼	Man cooly	0	3	0	,,	0	0	9
2	Boys	0	1	10	,,	0	3	8
	Sundries	...	...	...	...	0	0	8⅛
	For 100 sq. feet...	...	...	...	...	1	5	9

Quantity.	WORKMEN AND MATERIALS.	Rate. RS.	A.	P.	Per.	Amount. RS.	A.	P.
	Plastering 2 Coats chunam to new walls.	RS.	A.	P.		RS.	A.	P.
2½	Parahs of Chunam	3	8	0	18	0	7	9¼
½	Cart load of River sand	0	6	10	each	0	3	5
1–16	Cart load of white sand	0	13	6	"	0	0	10⅛
1	lb. of Jaggery	...	...	...	"	0	1	0½
2	Bricklayers	0	6	3	"	0	12	6
¼	Man cooly	0	3	0	"	0	0	9
1	Woman cooly	0	2	2	"	0	2	2
1¾	Boys	0	1	10	"	0	3	2½
	Sundries	...	...	...	...	0	0	5⅝
	For 100 sq. feet...	...	...	...	...	2	0	2
	Plastering 3 Coats chunam to new walls.							
4	Parahs of Chunam	3	8	0	18	0	12	5
¾	Cart load of River sand	0	6	10	each	0	5	1½
1–16	Cart load of white sand	1	11	0	"	0	1	8¼
2	lbs. of Jaggery	0	1	0½	lb.	0	2	1
3¾	Bricklayers	0	6	3	each	1	7	5¼
1¼	Man cooly	0	3	0	"	0	3	9
2	Women cooly	0	2	2	"	0	4	4
3¾	Boys	0	1	10	"	0	6	10½
	Sundries	...	...	...	...	0	0	11½
	For 100 sq. feet...	...	...	...	...	3	12	8
	Whitewashing 2 Coats to Walls and Cornices.							
1	Parah of Chunam	3	8	0	18	0	3	1¼
7½	Pollums Gum	0	4	6	viss	0	0	10⅛
¾	Measure raw Rice	0	1	6	each	0	1	1½
1¾	Bricklayers	0	6	3	"	0	10	11
¾	Man cooly	0	3	0	"	0	2	3
1	Woman cooly	0	2	2	"	0	2	2
2½	Boys	0	1	10	"	0	4	7
	Sundries	...	...	...	...	0	0	9⅞
	For 1,000 sq. feet...	...	..	...	...	1	9	10
	For 100 sq. feet...	...	..	...	...	0	2	7
	Yellow-washing in chunam, 2 Coats.							
1	Parah of Chunam	3	8	0	18	0	3	1¼
3¾	Viss yellow ochre	0	2	0	viss	0	7	6
7½	Pollums Gum	0	4	6	"	0	0	10⅛
¾	Measure raw Rice	0	1	6	each	0	1	1½
1¾	Bricklayer	0	6	3	"	0	10	11¼
¾	Man cooly	0	3	0	"	0	2	3
1	Woman cooly	0	0	2	2	0	2	2
3	Boys	0	0	1	10	0	5	6
	Sundries	...	...	...	...	0	1	6⅞
	For 1,000 sq. feet...	...	...	...	...	2	3	0
	For 100 sq. feet...	...	...	...	...	0	3	6

Quantity.	WORKMEN AND MATERIALS.	Rate. RS.	A.	P.	Per.	Amount. RS.	A.	P.
	Teakwood Brestsummers, Beams, Purlins, Joists, Rafters, Lintels, Door planks, Shelf planks, Brackets, and other Frames, &c., in average for 1 Cubic foot of wrought Timber.							
1	Cubic foot of wrought Timber............	2	6	0	c. ft.	2	6	0
	Nails of sorts..............................	...	...	...	,,	0	1	6
¼	Sawyers....................................	0	6	3	each	0	1	6¾
½	Carpenter	0	7	6	,,	0	3	9
¼	Man cooly..................................	0	3	0	,,	0	0	9
	Cart hire for conveying the materials from the Carpenters' workyard to the different works under execution..............	...	...	...	,,	0	0	9
	Sundries for chalk, twine and cooly hire for raising the Beams, &c.	...	...	...	,,	0	0	8¼
	For 1 Cubic foot of wrought Timber..	...	...	...	...	2	15	0
	1 Pair Paneled Venetian door with frame, hooks, hinges and bolts complete, 8 × 4 feet.							
	27′ × 5½″ × 3½″ door frame.							
	18½ 4½ 1¾ hinge styles & top rails.							
	15 4 1½ centre or middle styles.							
	3½ 7 1½ bottom rails.							
	3 10 1½ lock rails.							
	2¼ 1¼ 1 2 planks.							
	36 6 ⅝ 26 venetians.							
	7′ 1″ 7¼″ rough timber	2	6	0	c. ft.	16	15	15-16
24	lbs. wrought iron for 4 hooks and hinges..	0	2	0	lb.	3	0	0
3¾	Running feet, Iron round bolt	3	8	0	14	0	15	0
2	Doz. screws, 1¼ in.	0	1	3	14	0	2	6
2½	Doz. do. ¾ in.	0	0	9	,,	0	1	10½
26	Iron hasps, Bengal muster..................	3	4	0	c. 100	0	13	6
4½	Sawyers....................................	0	6	3	each	1	12	1½
14	Carpenters..................................	0	7	6	,,	6	9	0
5	Men cooly	0	3	0	,,	0	15	0
	Sundries	...	...	...	,,	0	3	11
	For 32 sup. feet...	...	...	...	...	31	8	0
	For 1 sup. foot...	...	...	...	...	0	15	9
	Attic window shutter with frame, axle and ropes, 4½′ × 2½′.							
	16′ × 5″ × 3″ frames. } 2,′ 8,″ 1 5-16.							
	12½ 3 1¼ styles. }							
	3¾ 1¼ 1 plank. }							
	2,′ 8,″ 1 5-16 rough timber.....................	2	6	0	c. ft.	6	5	8⅛
2	Iron axles with sockets, screws, &c..........	...	...	...		1	4	0
1	Iron bolt with screws........................	...	...	...		0	12	0
¾	Viss Cotton rope	1	4	0	viss	0	15	0
2	Sawyers......................................	0	6	3	each	0	12	6
6½	Carpenters..................................	0	7	6	,,	3	0	9
2	Men coolies	0	3	0	,,	0	6	0
	Sundries	...	...	...		0	1	6⅞
	For 11¼ sq. feet...	...	...	...	...	13	9	6
	For 1 sq. foot...	...	...	...	...	1	3	4

Brick-work in chunam with stock made Bricks for 74 cubic feet.

1,000	Pressed wall bricks, 8¾″ × 4″ × 2½″	2	Bricklayers.
6	Parahs of Chunam.	¼	Man cooly.
1¾	Cart load of River sand.	4½	Boys.
1	℔. of Jaggery.		Contingencies.

For 1 cubic foot, Annas 3-9¼.

Brick-work with Hydraulic cement 55 cubic feet.

1,100	Wall bricks, 1st & 2nd sort.	2	Bricklayers.
2⅓	Carts hire for do.	1	Man cooly.
3	Parahs of lime Chunam.	2	Women coolies.
3	Parahs of clay powder.	5	Boys.
3	Parahs of River sand.		Contingencies.

For 1 cubic foot, Annas 3.

Circular Archwork with Hydraulic cement including centring 15′ × 1⅓′ × 1⅓′.

305	Whole wall bricks.	2	Parahs River sand.
305	Arch bricks.	6	Bricklayers.
150	Wall bricks, 3rd sort.	1	Man cooly.
1⅞	Cart hire for do.	6	Boys.
1	Cart load of sandy clay.	2	Women coolies.
2	Parahs of lime Chunam.		Contingencies.

For 1 cubic foot, Annas 4-6.

Archwork in Chunam for Drains including centring 10′ × 4½′ × ¾′.

610	Whole wall bricks.	¼	Cart load of sandy clay.
50	Wall bricks, 3rd sort.	1	℔. of Jaggery.
1⅝	Cart hire for do.	2	Bricklayers.
4	Parahs of Chunam.	⅛	Man cooly.
⅞	Cart load of River sand.	4	Boys.

For 1 cubic foot, Annas 3-1.

Cordon work in Chunam for Fortification.

100	Bricks, 18″ × 5″ × 2½″.	1	℔. of Jaggery.
1	Cart hire for do.	1¼	Bricklayer.
2	Parahs of Chunam.	¼	Man cooly.
½	Cart load of River sand.	2¾	Boys.

For 1 running foot, Annas 9-1.

Cordon work in Chunam for Bridges.

1,200	Whole wall bricks.	3	℔s. of Jaggery.
3	Carts hire for do.	3⅓	Bricklayers.
7	Parahs of Chunam.	¾	Man cooly.
1½	Cart load of River sand.	6	Boys.

For 1 cubic foot, Annas 3-1.

One column 6 feet high and ¾ feet diam. complete, inclusive of plastering.

130	Pillar bricks, 9 in. diam.	1-16	Cart load of white sand.
15	Wall bricks, 1st & 2nd sort.	1½	℔. of Jaggery.
4	Bricks, 10 inches square.	2½	Bricklayers.
4	do. 8 do.	¼	Man cooly.
¼	Cart hire for do.	½	Woman cooly.
2	Parahs of Chunam.	2	Boys.
⅜	Cart load of River sand.		Contingencies.

For 1 running foot, Annas 8.

One column 8 *feet high and* 1 *feet diam. complete, inclusive of plastering.*

180	Pillar bricks, 1 foot diam.	1-16	Cart load of white sand.
16	Wall bricks, 1st & 2nd sort.	2¼	lbs. of Jaggery.
6	Bricks, 12 inches square.	3½	Bricklayers.
4	Do. 8 do.	¼	Man cooly.
9-16	Cart hire for do.	½	Woman cooly.
3	Parahs of Chunam.	3½	Boys.
⅝	Cart load of River sand.		Contingencies.

For 1 running foot, Annas 10.

Column 10 *feet high and* 1¼ *feet in diam., including plastering. Madras.*

180	Pillar Bricks.	1-16	Cart load of white sand.
16	Wall bricks.	3	lbs. of Jaggery.
4	Bricks, 10 inches square.	5½	Bricklayers.
¾	Cart hire for the above.	½	Man Cooly.
3	Round granite stones 1' in diam.	1	Woman.
4½	Parahs of Chunam.	5½	Boys.
1	Cart load of sand.		Contingencies.

For 1 running foot, Annas 14-3.

One column 14 *feet high and* 1¾ *feet diam. complete, including plastering.*

260	Pillar bricks, 1¾' diam.	1-16	Cart load of white sand.
40	Wall bricks, 1st & 2nd sort.	6	lbs. of Jaggery.
4	Bricks, 12 in. square.	11	Bricklayers.
2⅞	Cart hire for do.	1½	Man cooly.
3	Round Granite stones, 1½' diam.	2	Women cooly
9	Parahs of Chunam.	11	Boys.
1¾	Cart load of River sand.		Contingencies.

For 1 running foot, Rupee 1-5-1.

One column 16 *feet high and* 2 *feet diam. complete, including plastering.*

270	Pillar bricks, 2 feet diam.	⅛	Cart load of white sand.
50	Wall bricks, 1st & 2nd sort.	7	lbs. of Jaggery.
4	Bricks, 12 inches square.	14	Bricklayers.
4 9-16	Carts hire for do.	2	Men coolies.
4	Granite stones, 1¾' diam.	2½	Women coolies.
11	Parahs of Chunam.	14	Boys.
2	Carts load River sand.		Contingencies.

For 1 running foot, Rupee 1-12-7½.

One column 18 *feet high and* 2¼ *feet diam. complete, including plastering.*

290	Pillar bricks, 2¼ feet diam.	⅛	Cart load of white sand.
60	Wall bricks, 1st & 2nd sort.	8	lbs. of Jaggery.
6	Bricks, 12 in. square.	18	Bricklayers.
5	Carts hire for do.	3	Men coolies.
4	Granite stones, 2 feet diam.	3	Women coolies.
14	Parahs of Chunam.	18	Boys.
2½	Carts load of River sand.		Contingencies.

For 1 running foot, Rupee 1-14-3.

One column 23 *feet high and* 2½ *feet diam. complete, including plastering.*

400	Pillar bricks, 2½ feet diam.	⅛	Cart load of white sand.
75	Wall bricks, 1st & 2nd sort.	10	lbs. of Jaggery.
8	Bricks, 12 in. square.	22	Bricklayers.
8⅜	Carts hire for do.	4	Men coolies.
5	Granite stones, 2¾ feet diam.	3	Women coolies.
21	Parahs of Chunam.	24	Boys.
4¼	Carts load of River sand.	2	Stone-cutters.

For 1 running foot, Rupees 2-9-0.

One space of Balustrade with Pedestal and 3 coats plastering for 10 running feet.

265	Wall bricks, 1st & 2nd sort.	5	lbs. of Jaggery.
100	Thin flat Tiles.	10	Bricklayers.
11-16	Cart hire for do.	1	Man cooly.
9	Parahs of Chunam.	2	Women coolies.
1½	Cart load of River sand.	6	Boys.
1-16	Do. of white sand.		Contingencies.

For 1 running foot, Annas 15-3.

Honeycomb work with Pan Tiles in Chunam 100 square feet.

1,800	Pan Tiles.	1	lb. of Jaggery.
1¾	Cart hire for do.	1½	Bricklayer.
2	Parahs of Chunam.	½	Man cooly.
½	Cart load of River sand.	4	Boys.

For 1 square foot, Anna 1-3.

Honeycomb work with wall bricks and plastering 2 coats Chunam 8′ × 4′.

300	Wall bricks.	2	lbs. of Jaggery.
¾	Cart hire for do.	5	Bricklayers.
7	Parahs of Chunam.	¾	Man cooly.
1¼	Cart load of River sand.	6	Boys.
1-16	Do. of white sand.	1	Woman cooly.

For 1 square foot, Annas 3-4.

Trellis work with square Tiles and plastering 2 coats Chunam 10′ × 2′.

400	Flat Tiles.	1¼	lbs. of Jaggery.
¼	Cart hire for do.	6	Bricklayers.
3½	Parahs of Chunam.	½	Man cooly.
¾	Cart load of River sand.	1	Woman cooly.
1-16	Do. of white sand.	5	Boys.

For 1 sup. foot, Annas 4-5½.

Underpinning with brick-Jelly in Chunam.

¼	Cart load of Brick-Jelly.	1¼	lbs. of Jaggery.
¼	Cart hire for do.	1½	Bricklayer.
2½	Parahs of Chunam.	½	Man cooly.
¼	Cart load of River sand.	2½	Boys.

For 100 square feet, Rupee 1-14-6.

Flooring with Brick-jelly in Chunam 3″ thick and well rubbed over.

1½	Cart load of Brick-jelly.	2	lbs. of Jaggery.
1½	Cart hire for do.	1½	Bricklayer.
3	Parahs of Chunam.	¾	Man cooly.
¼	Cart load of River sand.	3	Boys.

For 100 square feet, Rupees 3-5-7.

Paving with brick-on-edge in Chunam and-rubbed over.

800	Wall bricks, 1st and 2nd sort.	2	lbs. of Jaggery.
2	Carts hire.	2¼	Bricklayers.
1¼	Cart load of River sand.	½	Man cooly.
5	Parahs of Chunam.	4½	Boys.

For 100 square feet, Rupees 7-3-3.

Paving with 6 inches square bricks.

410	Square bricks, 6 in. square.	2	lbs. of Jaggery.
1	Cart hire for do.	1¾	Bricklayer.
3½	Parahs of Chunam.	½	Man cooly.
1	Cart load of River sand.	4½	Boys.

For 100 square feet, Rupees 5-10-1.

Paving with 10 *inches square bricks.*

145	Square bricks, 10 in. square.	2	lbs. of Jaggery.
$1\frac{3}{8}$	Cart hire for do.	$1\frac{3}{4}$	Bricklayer.
$3\frac{1}{2}$	Parahs of Chunam.	$\frac{1}{2}$	Man cooly.
1	Cart load of River sand.	$4\frac{1}{2}$	Boys.

For 100 square feet, Rupees 6-5-3.

Paving with 12 *inches square bricks.*

103	Square bricks, 12 in. square.	2	lbs. of Jaggery.
$1\frac{3}{4}$	Cart hire for do.	$1\frac{3}{4}$	Bricklayer.
$3\frac{1}{2}$	Parahs of Chunam.	$\frac{1}{2}$	Man cooly.
1	Cart load of River sand.	$4\frac{1}{2}$	Boys.

For 1 square, Rupees 7-12-10.

Paving with granite stone in Chunam.

100	Running feet by 5 in. by 12 in. dressed 1 line and delivered on the work and fitting the same.	$1\frac{1}{2}$	Cart load of River sand.
		3	lbs. of Jaggery.
		$3\frac{1}{2}$	Bricklayers.
$\frac{1}{8}$	Cart load of Brick-jelly.	3	Men coolies.
$\frac{1}{8}$	Cart hire.	4	Boys.
6	Parahs of Chunam.		Contingencies.

For 100 square feet, Rupees 24-9-4.

Paving with smooth 12 *inches square granite stone in Chunam.*

100	Granite stones, 12 in. square and delivered on the work, smoothed with steel grits and fitted.	3	lbs. of Jaggery.
		$3\frac{1}{2}$	Bricklayers.
		2	Men coolies.
5	Parahs of Chunam.	5	Boys.
$1\frac{1}{2}$	Cart load of sand.		Contingencies.

For 100 square feet, Rupees 41-11-6.

Flooring with Asphalte $\frac{3}{4}$ inch thick.

400	lbs. of Asphalte.	$1\frac{1}{4}$	Bricklayer.
$\frac{3}{8}$	Cart load of River sand.	$1\frac{1}{2}$	Man cooly.
15	Pollums of Gingelly oil.	$1\frac{1}{4}$	Boy.
300	Pieces of fire-wood.	$\frac{1}{2}$	Woman for grinding.

For 100 square feet, Rupees 12-10-0.

Flooring with Asphalte 1 *inch thick.*

532	lbs. of Asphalte.	$1\frac{1}{2}$	Bricklayer.
7-16	Cart load of River sand.	2	Men coolies.
20	Pollums of Gingelly oil.	$1\frac{1}{2}$	Boy.
400	Pieces of fire-wood.	$\frac{1}{2}$	Woman for grinding.

For 100 square feet, Rupees 16-10-0.

Pointing in Chunam to Walls, Pillars, &c.

$\frac{3}{4}$	Parah of Chunam.	1	Bricklayer.
$\frac{1}{8}$	Cart load of River sand.	$\frac{1}{4}$	Woman cooly.
$\frac{1}{2}$	lb. of Jaggery.	1	Boy.

For 100 square feet, Annas 12-7.

Pointing in Chunam to 6 inches square brick floor.

$\frac{1}{4}$	Parah of Chunam.	$1\frac{3}{4}$	Bricklayer.
1-16	Cart load of River sand.	$\frac{1}{4}$	Woman cooly.
$\frac{1}{4}$	lb. of Jaggery.	$\frac{1}{2}$	Boy.

For 100 square feet or 400 running feet, Annas 11-6.

Pointing in chunam to 8 inches square brick floor.

¼	Parah of Chunam.	1	Bricklayer.
1-16	Cart load of River sand.	¼	Woman cooly.
¼	lb. of Jaggery.	½	Boy.

For 100 square feet or	300	running feet,	8	Inches—Annas	9-6.
For	240	„	10		7-10.
For	200	„	12		7-1.

*Terracing only with Brick-on-edge in chunam.**

2,000	Terrace Bricks.	1	lb. of Jaggery.
1 13-16	Cart hire for do.	1½	Bricklayer.
3	Parahs of Chunam.	½	Man cooly.
⅝	Cart load of River sand.	3	Boys.

For 100 square feet, Rupees 8-3-0.

Levelling course of wall bricks over the above for Terracing.

200	Wall Bricks, 1st & 2nd sort.	⅛	Cart load of River sand.
½	Cart hire for do.	½	Bricklayer.
½	Parah of Chunam.	1	Boy.

For 100 square feet, Rupee 1-8-3.

Brick-jelly in chunam 3 inches thick over the above for Terracing.

1½	Cart load of Brick-jelly.	½	Bricklayer.
1½	Cart hire for do.	½	Man cooly.
1½	lb. of Jaggery.	3	Boys.
3	Parahs of Chunam.		Contingencies.

For 100 square feet, Rupees 2-12-8.

Laying 3 courses of Flat Tiles in chunam over the above for Terracing.

1,200	Thick flat Tiles.	2¼	lbs. of Jaggery.
500	Thin do.	1½	Bricklayer.
17-16	Cart hire for the above.	¾	Man cooly.
4½	Parahs of Chunam.	4	Boys.
1⅛	Cart load of River sand.		Contingencies.

For 100 square feet, Rupees 8.

Plastering 3 Coats chunam over the Tiles or Terrace.

4	Parahs of Chunam.	3	Bricklayers.
1	Cart load of River sand.	¾	Man cooly.
1-16	Cart load of white sand.	2	Women coolies.
2	lbs. of Jaggery.	5	Boys.

For 100 square feet, Rupees 3-12-1.

Plastering 3 Coats chunam to Ceiling (spaces between Joists.)

3	Parahs of Chunam.	3	Bricklayers.
⅝	Cart load of River sand.	½	Man cooly.
1-16	Cart load of white sand.	2	Women coolies.
1½	lb. of Jaggery.	4	Boys.

For 100 square feet, Rupees 3 2-0.

* *Terracing with Brick-jelly, 3 inches thick, 3 courses of Flat Tiles, and plastering 3 Coats of chunam to top of Terrace over sheathing boards.*

1,200	Thick flat Tiles.	1-16	Cart load of white sand.
500	Thin do.	6	lbs. of Jaggery.
200	Wall bricks, 1st & 2nd sort.	5¼	Bricklayers.
1½	Cart load of Brick-jelly.	2	Men coolies.
3⅝	Carts hire for the above.	2	Women coolies.
12	Parahs of Chunam.	12	Boys.
2	Carts load of River sand.		Contingencies.

For 100 square feet, Rupees 15-10-0.

* For the complete datum, see page 167.

*Particulars of sloping Roof with Flat and Pan tiles.—1st—Flat Tiles.**

500	Thin flat Tiles.	1	℔. of Jaggery.
$\frac{3}{8}$	Cart hire for do.	$\frac{3}{4}$	Bricklayer.
7-16	Cart load of River sand.	$\frac{3}{8}$	Man cooly.
2	Parahs of Chunam.	2	Boys.

For 100 square feet, Rupees 2-11-9.

2nd—Pan tiles.

1,500	Pan Tiles.	$\frac{3}{8}$	Man cooly.
$1\frac{1}{2}$	Cart hire for do.	$1\frac{1}{2}$	Boy.
$\frac{3}{4}$	Bricklayer.		Contingencies.

For 100 square feet, Rupees 5-8-4.

3rd—Chunam borders.

$1\frac{3}{4}$	Parah of Chunam.	$\frac{1}{2}$	Bricklayer.
9-16	Cart load of River sand.	$\frac{1}{4}$	Man cooly.
$\frac{1}{2}$	*℔. of Jaggery.*	$1\frac{1}{2}$	*Boy.*

For 100 square feet, Rupee 1-0-11.

Plastering 2 Coats of Yellow colored chunam for Walls.

$2\frac{1}{2}$	Parahs of Chunam.	1	℔. of Jaggery.
9-16	Cart load of River sand.	2	Bricklayers.
1	Viss yellow ochre or 100 Cocoanut shells for Blue colored Chunam.	$\frac{1}{2}$	Man cooly.
		1	Woman cooly.
		2	Boys.

For 100 square feet, Yellow, Rupees 2-3-1.

For „ Blue, „ 2-3-3.

Plastering 3 Coats of Yellow colored chunam for Walls.

4	Parahs of Chunam.	2	℔s. of Jaggery.
$\frac{3}{4}$	Cart load of River sand.	4	Bricklayers.
$1\frac{1}{2}$	Viss Yellow ochre or 150 Cocoanut shells for Blue colored Chunam.	$1\frac{1}{2}$	Man cooly.
		$2\frac{1}{2}$	Women coolies.
		4	Boys.

For 100 square feet, Yellow, Rupees 4-1-9.

For „ Blue, „ 4-2-3.

Plastering 2 Coats Blue colored chunam for Floors.

$2\frac{1}{2}$	Parahs of Chunam.	$2\frac{1}{4}$	Bricklayers.
9-16	Cart load of River sand.	$\frac{1}{2}$	Man cooly.
100	Cocoanut shells.	1	Woman cooly.
1	℔. of Jaggery.	2	Boys.

For 100 square feet, Blue, Rupees 2-4-10.

For „ Yellow, „ 2-4-7.

Plastering 3 Coats Blue colored chunam for Floors.

4	Parahs of Chunam.	$4\frac{1}{4}$	Bricklayers.
$\frac{3}{4}$	Cart load of River sand.	$1\frac{1}{2}$	Man cooly.
150	Cocoanut shells.	$2\frac{1}{2}$	Women coolies.
2	℔s. of Jaggery.	4	Boys.

For 100 square feet, Blue, Rupees 4-4-0.
For „ Yellow, „ $4\text{-}3\text{-}9\frac{1}{3}$.
For „ Red, „ $4\text{-}3\text{-}6\frac{1}{2}$.

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* For the complete datum, see page 170.

Plastering floors with 3 Coats White and Yellow or White and Red colored chunam in squares.

4 Parahs of Chunam.	5⅓ Bricklayers.
11-16 Cart load of River sand.	1⅓ Man cooly.
1 Viss yellow or red ochre.	2⅓ Women coolies.
2 lbs. of Jaggery.	4 Boys.

For 100 sq. ft. White and Yellow squares, or White and Red squares, Rs. 4-10-5.
For 100 sq. ft. White and Blue squares, Rs. 4-10-8.

Plastering floors with 3 Coats of Red, White & Blue colored chunam in squares.

4 Parahs of Chunam.	2 lbs. of Jaggery.
11-16 Cart load of River sand.	8 Bricklayers.
1-32 Cart load of white sand.	1½ Man cooly.
¾ Viss yellow ochre.	3 Women coolies.
¾ Viss red ochre.	5 Boys.
75 Cocoanut shells.	Contingencies.

For 100 square feet, Rupees 6-1-0.

Plastering 2 Coats chunam to Cornices.

3½ Parahs of Chunam.	3 Bricklayers.
10-16 Cart load of River sand.	¾ Man cooly.
1-16 Cart load of white sand.	1½ Woman cooly.
2 lbs. of Jaggery.	3 Boys.

For 100 square feet, Rupees 3-1-6.

Plastering 3 Coats chunam to Cornices.

6 Parahs of Chunam.	8 Bricklayers.
1⅛ Cart load of River sand.	1½ Man cooly.
⅛ Cart load of white sand.	2¼ Women coolies.
3 lbs. of Jaggery.	5 Boys.

For 100 square feet, Rupees 6-6-4.

Plastering 2 Coats chunam to Walls, &c., with rustic work.

3½ Parahs of Chunam.	2½ Bricklayers.
⅝ Cart load of River sand.	½ Man cooly.
1-16 Cart load of white sand.	1 Woman cooly.
1 lb. of Jaggery.	2½ Boys.

For 100 square feet, Rupees 2-10-8.

Plastering 3 Coats chunam to Walls, &c., with rustic work.

5 Parahs of Chunam.	4½ Bricklayers.
⅞ Cart load of River sand.	1½ Man cooly.
1-16 Cart load of white sand.	2 Women coolies.
2 lbs. of Jaggery.	4½ Boys.

For 100 square feet, Rupees 4-7-8⅓.

Plastering 2 Coats chunam to Ceilings (without Joists) or under-arched Roofs.

3 Parahs of Chunam.	2½ Bricklayers.
⅝ Cart load of River sand.	½ Man cooly.
1-16 Cart load of white sand.	1 Woman cooly.
1 lb. of Jaggery.	2½ Boys.

For 100 square feet, Rupees 2-8-11.

Plastering 3 Coats chunam to Ceilings (without Joists) or under-arched Roofs.

4½ Parahs of Chunam.	4½ Bricklayers.
¾ Cart load of River sand.	1½ Man cooly.
1-16 Cart load of white sand.	2 Women coolies.
2 lbs. of Jaggery.	4½ Boys.

For 100 square feet, Rupees 4-5-2.

Plastering over Lathing.

7½ Parahs of Chunam.	½ Viss hair.
1¼ Cart load of River sand.	5½ Bricklayers.
⅛ Cart load of white sand.	2 Men coolies.
4 lbs. of Jaggery.	3 Women coolies.
½ Viss hemp.	7 Boys.

For 100 square feet, Rupees 6-8-0.

Plastering 1 Coat cement chunam.

2 Parahs of Chunam.	¾ lb. of Jaggery.
⅛ Cart load of River sand.	1 Bricklayer.
⅛ Cart load of Brick-jelly.	1 Man cooly.
⅛ Cart hire for do.	2½ Boys.

For 100 square feet, Rupee 1-7-7.

Plastering 2 Coats cement chunam.

2¼ Parahs of Chunam.	2 Bricklayers.
⅛ Cart load of Brick-jelly.	½ Man cooly.
⅛ Cart hire for do.	1 Woman cooly.
⅜ Cart load of River sand.	1¾ Boys.
1 lb. of Jaggery.	Contingencies.

For 100 square feet, Rupees 2-0-2½.

Repairing plastering with 1 Coat chunam.

2 Parahs of Chunam.	1 Bricklayer.
⅛ Cart load of River sand.	½ Man cooly.
⅜ lb. of Jaggery.	2½ Boys.

For 100 square feet, Rupee 1-7-3.

Repairing plastering with 2 Coats chunam.

2½ Parahs of Chunam.	2 Bricklayers.
½ Cart load of River sand.	½ Man cooly.
1-16 Cart load of white sand.	1 Woman cooly.
1 lb. of Jaggery.	2 Boys.

For 100 square feet, Rupees 2-1-5.

Repairing plastering with 3 Coats chunam.

4 Parahs of Chunam.	4 Bricklayers.
¾ Cart load of River sand.	1½ Man cooly.
1-16 Cart load of white sand.	2 Women coolies.
2 lbs. of Jaggery.	4 Boys.

For 100 square feet, Rupees 3-15-8.

Bluewashing in chunam, 2 Coats for 1,000 square feet.

1	Parah of Chunam.	1⅔	Bricklayer.
400	Cocoanut shells.	¾	Man cooly.
7½	Pollums of Gum.	1	Woman cooly.
¾	Measure of Raw rice.	3	Boys.

For 100 square feet, Annas 3-6.

Whitewashing in chunam, 2 Coats to Ceilings for 1,000 square feet.

1	Parah of Chunam.	¾	Man cooly.
7½	Pollums of Gum.	1	Woman cooly.
¾	Measure of Raw rice.	2⅓	Boys.
2	Bricklayers.		Contingencies.

For 100 square feet, Annas 2-9.

Taking off 1 course thick flat Tiles from a Terrace and replacing with new and plastering 3 Coats of chunam.

600	Thick flat Tiles.	3	lbs. of Jaggery.
½	Cart hire for do.	3¼	Bricklayers.
6	Parahs of Chunam.	1½	Man cooly.
1⅜	Cart load of River sand.	2	Women coolies.
1-16	Cart load of white sand.	6¼	Boys.

For 100 square feet, Rupees 6-7-6.

Removing Tiles of Roof and replacing them, using half portion new Flat and Pan Tiles and new chunam borders.

250	Flat Tiles.	1½	lb. of Jaggery.
750	Pan Tiles.	2	Bricklayers.
1	Cart hire for do.	1½	Man cooly.
3¾	Parahs of Chunam.	6⅓	Boys.
1	Cart load of River sand.		Contingencies.

For 100 square feet, Rupees 6-6-0.

Removing Tiles of Roof and replacing them, using half portion new Flat Tiles and one-third portion Pan Tiles and new chunam borders.

250	Flat Tiles.	1½	lb. of Jaggery.
500	Pan Tiles.	2	Bricklayers.
¾	Cart hire for do.	1⅓	Man cooly.
3¾	Parahs of Chunam.	6¼	Boys.
1	Cart load of River sand.		Contingencies.

For 100 square feet, Rupees 5-8-0.

Removing Tiles of Roof and replacing them, using half portion new Flat Tiles and quarter portion Pan Tiles and new chunam borders.

250	Flat Tiles.	1½	lb. of Jaggery.
375	Pan Tiles.	2	Bricklayers.
⅝	Cart hire for do.	1½	Man cooly.
3¾	Parahs of Chunam.	6	Boys.
1	Cart load of River sand.		Contingencies.

For 100 square feet, Rupees 5-1-0.

Removing Tiles of Roof and replacing them, using one-third portion new Flat and Pan Tiles and new chunam borders.

167 Flat Tiles.	1½ lb. of Jaggery.
500 Pan Tiles.	2 Bricklayers.
11-16 Cart hire for do.	1½ Man cooly.
3¾ Parahs of Chunam.	6 Boys.
1 Cart load of River sand.	Contingencies.

For 100 square feet, Rupees 5-3-6.

Removing Tiles of Roof and replacing them, using one-third new Flat Tiles and one-fourth portion new Pan Tiles and new chunam borders.

167 Flat Tiles.	1½ lb. of Jaggery.
375 Pan Tiles.	2 Bricklayers.
9-16 Cart hire for do.	1½ Man cooly.
3¾ Parahs of Chunam.	6 Boys.
1 Cart load of River sand.	Contingencies.

For 100 square feet, Rupees 4-13-0.

Removing Tiles of Roof and replacing them, using one-third portion new Flat Tiles and one-fifth portion new Pan Tiles and new chunam borders.

167 Flat Tiles.	1½ lb. of Jaggery.
300 Pan Tiles.	2 Bricklayers.
½ Cart hire for do.	1½ Man cooly.
3¾ Parahs of Chunam.	6 Boys.
1 Cart load of River sand.	Contingencies.

For 100 square feet, Rupees 4-9-0.

Removing Tiles of Roof and replacing them, using new Flat Tiles and one-third portion new Pan Tiles and new chunam borders.

500 Flat Tiles.	1½ lb. of Jaggery.
500 Pan Tiles.	2 Bricklayers.
⅞ Cart hire for do.	1½ Man cooly.
3¾ Parahs of Chunam.	6 Boys.
1 Cart load of River sand.	Contingencies.

For 100 square feet, Rupees 6-2-10.

Shifting Tiles and repairing chunam borders.

50 Pan Tiles.	¾ Bricklayer.
¼ Parahs of Chunam.	⅕ Man cooly.
1-16 Cart load of River sand.	½ Boy.

For 100 square feet, Annas 10.

Repointing joints of Flat Tiles between reepers and whitewashing inside Roofs with 2 Coats.

2 Parahs of Chunam.	3 Bricklayers.
⅜ Cart load of River sand.	¼ Man cooly.
1 Pollum of Gum.	¾ Woman cooly.
⅛ Measure of Raw Rice.	2 Boys.

For 100 square feet, Rupees 2-4-0.

Broken bottles in Chunam over copings for 20 running feet.

6	Baskets of broken bottles.	1	Bricklayer.
1	Parah of Chunam.	¼	Man cooly.
⅛	Cart load of River sand.	1¾	Boy.
½	lb. of Jaggery.		Contingencies.

For 1 running foot, Anna 1-2¼.

Pot Well for water, 3 feet diam. and 20 feet deep.

50	Pot rings.		Contract for sinking Well, Rs. 6½.
25	Men coolies.	20	Well ropes.
1	Cart load of clay.	4	Men for removing earth.
1	Bundle of straw.	6	Boys for do.

For each Well, Rupees 21-1-8.

Brick Well for water, 3 feet diam. and 25 feet deep, with Parapet.

7,200	Well bricks, 3 feet diam.	1½	Cart load of River sand.
18	Carts hire for do.	4	lbs. of Jaggery.
4½	Carts load of clay.	24	Bricklayers.
30	Black brushwood.	12	Men coolies.
3	Pala sticks.	1	Woman cooly.
1½	Viss loose coir.	50	Boys.
30	Well ropes.	1½	Carpenter.
2	Bundles of straw.	2	Well-sinkers.
10	Common baskets.		Contract for sinking Well, Rs. 3.
30	Sticks of firewood.		Contract for excavating & filling earth, Rupees 3½.
7	Parahs of Chunam.		

For each Well, Rupees 73-10.

Brick Well for water, 6 feet diam. and 25 feet deep, with Parapet.

11,200	Well bricks, 6 feet diam.	2½	Carts load of sand.
28	Carts hire for do.	45	Bricklayers.
7	Carts load of clay.	25	Men coolies.
50	Black brushwood.	80	Boys.
5	Pala sticks.	2	Women coolies.
3	Viss loose coir.	3	Carpenters.
42	Well ropes.	4	Well-sinkers.
4	Bundles of straw.		Contract for sinking Well, Rs. 8.
20	Common baskets.		Contract for excavating and filling earth, Rs. 10½.
50	Sticks of firewood.		Contingencies.
11	Parahs of Chunam.		

For each Well, Rupees 134.

Brick Wells for Foundations, 3 feet diam. by 6 feet deep, and filled in with Brick-jelly and sand.

1,750	Well bricks, 3 feet diam.	1½	Bundle of straw.
2½	Carts load of brick-jelly.	6	Common baskets.
6⅞	Carts hire for do.	30	Sticks of firewood.
1½	Cart load of River sand.	6	Bricklayers.
1	Cart load of clay.	3	Men coolies.
30	Black brushwood.	15	Boys.
3	Pala sticks.	1½	Carpenter.
1½	Viss loose coir.	2	Well-sinkers.
15	Well ropes.		Contract for sinking Well, R. 1¾.

For each Well, Rupees 24-2-6.

Brick Well for Foundations, 4 feet diam. by 6 feet deep, and filled in with Brick jelly and River sand.

2,300	Well bricks of 4 feet diam.	35	Sticks of firewood.
3	Carts load of brick-jelly.	2	Bundles of straw.
8¾	Carts hire for do.	16	Common baskets.
1½	Cart load of clay.	8	Bricklayers.
2	Carts load of River sand.	7	Men coolies.
35	Black brushwood.	20	Boys.
3½	Pala sticks.	2	Carpenters.
2	Viss loose coir.	3	Well-sinkers.
16	Well ropes.		Contract for sinking Well, Rs.

For each Well, Rupees 32-2-9.

Filling concrete for Foundations.

45	Parahs of gravel or stone.	5	Men coolies.
22½	Parahs of Chunam.	5	Women coolies.
22½	Parahs of sand.		Contingencies.

For 1 cubic foot, Annas 2.

Filling Hydraulic concrete (Beton) for Foundations.

25	Parahs of Brick-jelly.	9	Parahs of clay powder.
12½	Parahs of Laterite-jelly.	7	Parahs of River sand.
12½	Parahs of Gravel.	14	Men coolies.
9	Parahs of lime Chunam.	16	Women coolies.

For 1 cubic foot, Annas 3-6.

A Pair of Batten door with frame, hooks, hinges and bolts 8′ × 4′.

6′9″4″	Wrought Timber.	2½	Dozens of ¾ inch screws.
31	lbs. of Wrought iron for 4 hooks and 4 hinges.	8	Carpenters.
1½	lb. of Batten nails.	3½	Sawyers.
3¾	Running feet round iron for bolts.	3	Men coolies.
			Sundries.

For 1 square foot, Annas 13-7½.

1 *Pair of Batten door shutters, with hinges and bolts,* 7′ 6½″ × 3′ × 6½″.

3′2¼″	Rough Timber.	2½	Dozens of ¾ inch screws.
19	lbs. of Wrought iron for 4 hinges.	5¾	Carpenters.
1⅛	lb of Batten nails.	2½	Sawyers.
3¾	Running feet round iron for bolts.	2	Men coolies.

For 1 square foot, Annas 9-3½.

A door frame with hooks 8′ × 4′.

3′7″3¾″	Wrought Timber.	1	Sawyer.
12	lbs. of wrought iron for 4 hooks.	1	Man cooly.
2¼	Carpenters.		Sundries.

For 1 square foot, Annas 5-11.

A Pair of Paneled door with frames, hooks, hinges and bolts, 8′ × 4′.

6′6″1¾″	Wrought Timber.	2½	Dozens of ¾ inch screws.
24	lbs. of Wrought iron for hooks and hinges.	12	Carpenters.
3¾	Running feet round iron for bolts.	3½	Sawyers.
2	Dozen screws, 1¼ inch.	4	Men coolies.
			Contingencies.

For 1 square foot, Annas 14.

A Pair of Paneled venetian door shutters with hinges and bolts, $7'\,6\frac{1}{2}" \times 3'\,6\frac{1}{2}"$ *

3'6"$3\frac{1}{2}$" Wrought Timber.	26 Iron hasps, (Bengal muster.)
12 lbs. of wrought iron for hinges.	$3\frac{1}{4}$ Sawyers.
$3\frac{3}{4}$ Running feet round iron for bolts.	$11\frac{3}{4}$ Carpenters.
2 Dozens of screws, $1\frac{1}{4}$ in.	4 Men coolies.
$2\frac{1}{2}$ Do. do. $\frac{3}{4}$ in.	Sundries.

For 1 square foot, Annas 11-10.

A Pair of Paneled venetian doors with frame, folding hinges and bolts, $8' \times 4'$.

7'1"$7\frac{1}{4}$" Rough Timber.	26 Iron hasps, (Bengal muster.)
4 Iron folding hinges, 9 in. long.	$4\frac{1}{2}$ Sawyers.
$3\frac{3}{4}$ Running feet round iron for bolts.	14 Carpenters.
4 Dozens of screws, $1\frac{1}{4}$ in.	5 Men coolies.
$2\frac{1}{2}$ Do. $\frac{3}{4}$ in.	Sundries.

For 1 square foot, Annas 15-10.

1 *Door Frame without hooks.*

3'7"$3\frac{3}{4}$" Rough Timber.	$2\frac{1}{4}$ Carpenters.
1 Sawyer.	1 Man cooly.

For 1 square foot, Annas 5-2.

Bengal muster, fixed venetian blinds without hasps with frames, $18' \times 6'$.

24'5"9" Rough Timber.	20 Iron handles.
10 Dozens of screws, 3 in.	98 Carpenters.
9 Do. 1 in.	16 Sawyers.
10 Iron chains with pins	12 Men coolies.

For 1 square foot, Rupee 1-1-4.

1 *Pair of Paneled glazed door shutters, with brass folding hinges*, $8' \times 4'$.

3'0"$10\frac{3}{4}$" Rough Timber.	4 Dozens of screws, $\frac{3}{4}$ in.
6 Brass hinges, 4 in. long.	16 Panes of glass, $11" \times 8"$.
6 Running feet round iron for bolts.	$14\frac{1}{2}$ Carpenters.
$\frac{3}{4}$ Running foot brass cross bolt.	3 Sawyers.
2 Brass rings.	2 Men coolies.
2 Iron crane hooks with brackets.	Contract for fixing Glass, 1 R.
4 Dozens of screws, 1 in.	Sundries.

For 1 square foot, Annas 12-1.

1 *Pair of Batten window shutters with frames, hooks, hinges and iron bars*, $6' \times 4'$.

4'9"$4\frac{1}{4}$" Rough Timber.	1 lb. of batten nails.
22 lbs. of wrought iron for 4 hooks and 4 hinges.	$2\frac{3}{4}$ Sawyers.
125 lbs. of 1 in. square iron bars.	7 Carpenters.
2 Iron fastening or crane hooks.	2 Men coolies.
4 Small do. or Gontz.	Smith's hire for cutting bars, 4 annas.

For 1 square foot, Rupee 1-2-2.

1 *Pair of Batten window shutters with hinges*, $5\frac{5}{8}' \times 3\frac{1}{2}'$.

1'9"$1\frac{1}{3}$" Rough Timber.	1 lb. of batten nails.
12 lbs. of wrought iron for 4 hinges.	2 Sawyers.
2 Iron fastening or crane hooks.	5 Carpenters.
4 Small do. or Gontz.	$1\frac{1}{4}$ Man cooly.

For 1 square foot, Annas 7-10.

1 *Window frame with hooks and iron bars*, $6' \times 4'$.

3'0"3" Rough Timber.	$\frac{3}{4}$ Sawyer.
10 lbs. of wrought iron for 4 hooks.	2 Carpenters.
125 lbs. of 1 in. square iron bars.	Smith's cooly for cutting bars, 4 Annas.

For 1 square foot, Annas 11-9.

* For complete datum, see page 172.

1 *Pair of Batten window shutters with frame hooks, hinges and wooden bars*, 6′ X 4′.

4′9″4¼″ Rough Timber.	3 Sawyers.
1 Palmyra for bars.	8 Carpenters.
2 Iron fastening or crane hooks.	2 Men coolies.
4 Small do. or Gontz.	22 lbs. of wrought iron for 4 hooks and 4 hinges.
1 lb. of batten nails.	

For 1 square foot, Annas 13-10.

1 *Window frame with wooden bars and hooks*, 6′ X 4′.

3′0″3″ Rough iron.	1 Sawyer.
1 Palmyra for bars.	3 Carpenters.
10 lbs. of wrought iron for 4 hooks.	¾ Man cooly.

For 1 square foot, Annas 7-6.

1 *Pair of venetian window shutters with frame, hooks and hinges*, 6′ X 4′.

5′11″5¾″ Rough Timber.	4 Small hooks or Gontz.
22 lbs. of wrought iron.	3½ Sawyers.
40 Iron hasps, (Bengal muster.)	12 Carpenters.
2 Dozens of screws, 1¼ inch.	2½ Men coolies.
2 Iron fastening or crane hooks, 1¼ foot.	Sundries.

For 1 square foot, Rupee 1-1-7.

1 *Pair af venetian shutters with hinges*, 5⅝′ X 3½′.

2′11″2¾″ Rough Timber.	4 Small hooks or Gontz.
12 lbs. of wrought iron.	2¾ Sawyers.
40 Iron hasps, (Bengal muster.)	10 Carpenters.
2 Dozens of screws, 1¼ inch.	1¾ Man cooly.
2 Iron fastening or crane hooks.	Sundries.

For 1 square foot, Annas 13-4.

1 *Window frame with hooks without any bars*, 6′ X 4′.

3′0″3″ Rough Timber.	2 Carpenters.
10 lbs. of wrought iron.	¾ Man cooly.
¾ Sawyer.	Sundries.

For 1 square foot, Annas 6-7.

1 *Pair of glazed shutters with brass hinges*, 6′ X 4′.

1′5″4¾″ Rough Timber.	24 Panes of glass, 13″ X 11″.
4 Brass hinges, 4 inches.	2 Sawyers.
2¾ Dozens of screws, 1 inch.	7 Carpenters,
2 Buttons with screws.	1½ Man cooly.
2 Iron fastening hooks, 1¼ foot.	Contract for fixing Glass, R. 1½.
2 Brass rings.	Sundries.

For 1 square foot, Annas 11-3½.

1 *Semi-circular Fan Light*, 4½′ X 2¼′.

1′5″3¾″ Rough Timber.	2 Men coolies.
4 Screws.	Contract for fixing glass with putty, Rupee 1.
16 Panes of glass, 12″ by 8″.	Sundries.
2 Sawyers.	
9 Carpenters.	

For 1 square foot, Rupee 1-2-10.

Teakwood Water Spout, 12 feet long and 6 inches square, with iron hoops and cramps and painting with Tar, pitch and cloth.

1′3″9″ Rough Timber.	½ Viss Pitch.
1 lb. of batten nails.	3¼ Cubic feet of coarse cloth.
4 Iron hoops of 6 in. square.	1 Sawyer.
3 Iron cramps.	2 Carpenters.
1½ Measure of Tar.	½ Man cooly.

For 1 running foot, Annas 11.

Lining with Teakwood planks and nails with battens over joists.

7′1″ Rough Timber.	7 Carpenters.
4 lbs. of batten nails.	2 Men coolies.
8 Sawyers.	Sundries.

For 100 square feet, Rupees 24-10.

Sloping roof with Palmyra rafters, reepers and nails.

8 Palmyras, 12 feet long.	1 lb. of Reeper nails.
21 Palmyra Reepers.	2 Carpenters.
Cart hire for do.	$1\frac{1}{2}$ Man cooly.
1 lb. of Rafter nails.	Sundries.

For 100 square feet, Rupees 9-14.

Roofing with Palmyra couples, reepers and nails.

10 Palmyras, 12 feet long.	$1\frac{1}{2}$ lb. of Reeper nails.
21 Palmyra Reepers.	3 Carpenters.
Cart hire for do.	$\frac{1}{4}$ Sawyer.
2 lbs. of Rafter nails.	2 Men coolies.

For 100 square feet, Rupees 12-3.

Roofing with Palmyra couples, with 2 collar rafters, reepers and nails.

12 Palmyras, 12 feet long.	$1\frac{1}{3}$ lb. of Reeper nails.
21 Palmyra Reepers.	$3\frac{1}{3}$ Carpenters.
Cart hire for do.	$\frac{1}{4}$ Sawyer.
$2\frac{1}{2}$ lbs. of Rafter nails.	$2\frac{1}{3}$ Men coolies.

For 100 square feet, Rupees 14.

Teakwood reepers and nails for sloping roof with Flat Tiles.

2′8″$9\frac{3}{4}$″ Rough Timber.	1 Carpenter.
$1\frac{1}{3}$ lb. of Reeper nails.	$\frac{1}{2}$ Man cooly.
$2\frac{1}{3}$ Sawyers.	Sundries.

For 100 square feet, Rupees 8-7.

Palmyra reepers and nails for roof with Flat Tiles.

21 Palmyra Reepers.	$\frac{3}{4}$ Carpenter.
Cart hire for do.	$\frac{1}{4}$ Man cooly.
$1\frac{1}{3}$ lb. of Reeper nails.	Sundries.

For 100 square feet, Rupees 2-14.

Palmyra reepers and nails for Roof with Pan Tiles.

25 Palmyra Reepers.	$\frac{3}{4}$ Carpenter.
Cart hire for do.	$\frac{1}{4}$ Man cooly.
$1\frac{3}{4}$ lbs. of Reeper nails.	Sundries.

For 100 square feet, Rupees 3-5.

1 *Pair of Paneled and railed Gate shutters with hinges and hooks laid in stone,* 8′ × $5\frac{3}{4}$′.

6′4″7″ Rough Timber.	1 Iron cross bolt, with hooks.
4 Granite stones with grooves.	26 Carpenters.
12 lbs. of lead.	5 Sawyers.
94 lbs. of wrought iron for 4 hooks and 4 hinges.	7 Men coolies.
	Sundries.

For 1 square foot, Rupee 1-1.

1 *Pair of railed Gate shutters without centre rail,* 8′ × $5\frac{3}{4}$′.

6′0″9″ Rough Timber.	26 Carpenters.
64 lbs. of wrought iron for 4 hinges.	4 Sawyers.
1 Iron cross bolt, $1\frac{1}{2}$ foot.	6 Men coolies.

For 1 square foot, Annas 13-$7\frac{1}{2}$.

Wood oil, 1 Coat.

½ Measure of wood oil.	½ Painter.
2 Pollums of white dammer.	Sundries.

For 100 square feet, Annas 8-6.

Wood oil, 2 Coats.

¾ Measure of wood oil.	¾ Painter.
3 Pollums of white dammer.	Sundries.

For 100 square feet, Annas 12-9.

Wood oil, 3 Coats.

1 Measure of wood oil.	1 Painter.
4 Pollums of white dammer.	Sundries.

For 100 square feet, Rupee 1-0-9.

Red paint, 1 Coat.

½ Viss of red ochre.	½ Grinder.
½ Measure of linseed oil.	½ Painter.

For 100 square feet, Annas 15.

Red paint, 2 Coats.

¾ Viss of red ochre.	¾ Grinder.
¾ Measure of linseed oil.	1 Painter.

For 100 square feet, Rupee 1-7-9.

Red paint, 3 Coats.

1 Viss of red ochre.	1 Grinder.
1 Measure of linseed oil.	1½ Painter.

For 100 square feet, Rupees 2-0-6.

White paint, 1 Coat.

⅝ Viss of white lead.	½ Grinder.
½ Measure of linseed oil.	½ Painter.

For 100 square feet, Rupee 1-3-9.

White paint, 2 Coats.

1 Viss of white lead.	1 Grinder.
¾ Measure of linseed oil.	1 Painter.

For 100 square feet, Rupees 2.

White paint, 3 Coats.

1¼ Viss of white lead.	1¼ Grinder.
1 Measure of linseed oil.	1½ Painter.

For 100 square feet, Rupees 2-11.

Lead color paint, 1 Coat.

⅝ Viss of white lead.	½ Grinder.
1½ Pollums of lamp black.	½ Painter.
½ Measure of linseed oil.	Sundries.

For 100 square feet, Rupee 1-4-3.

Lead color paint, 2 Coats.

1 Viss of white lead.	1 Grinder.
2 Pollums of lamp black.	1 Painter.
¾ Measure of linseed oil.	Sundries.

For 100 square feet, Rupees 2-0-9.

Lead color paint, 3 Coats.

1¼ Viss of white lead.	1¼ Grinder.
2½ Pollums of lamp black.	1½ Painter.
1 Measure of linseed oil.	Sundries.

For 100 square feet, Rupees 2-12-0.

Green Paint, 1 Coat.

1¼ lb. of green paint.	⅛ Grinder.
½ Measure of linseed oil.	½ Painter.

For 100 square feet, Rupee 1-1-3.

Green Paint, 2 Coats.

2 lbs. of green paint.	¼ Grinder.
¾ Measure of linseed oil.	1 Painter.

For 100 square feet, Rupee 1-12-0.

Green Paint, 3 Coats.

2 lbs. of green paint.	½ Grinder.
1 lb of white lead.	1½ Painter.
1 Measure of linseed oil.	Sundries.

For 100 square feet, Rupees 2-7-0.

Verdigris green paint, 1 Coat.

3-16 Viss of white lead.	½ Painter.
⅜ Viss of Verdigris, green.	2 Grinders.
½ Measure of linseed oil.	Sundries.

For 100 square feet, Rupees 2-10.

Verdigris green paint, 2 Coats.

¼ Viss of white lead.	1 Painter.
½ Viss of Verdigris, green.	4 Grinders.
¾ Measure of linseed oil.	Sundries.

For 100 square feet, Rupees 3-10.

Verdigris green paint, 3 Coats.

¾ Viss of white lead.	1½ Painter.
½ Viss of Verdigris, green.	4½ Grinders.
1¼ Measure of linseed oil.	Sundries.

For 100 square feet, Rupees 4-12.

Black paint, 1 Coat.

¾ lb. of lamp black.	¼ Grinder
½ Measure of linseed oil.	½ Painter.

For 100 square feet, Rupee 1.

Black paint, 2 Coats.

1¼ lb of lamp black.	½ Grinder.
¾ Measure of linseed oil.	1 Painter.

For 100 square feet, Rupee 1-10.

Black paint, 3 Coats.

1¾ lb. of lamp black.	¾ Grinder.
1 Measure of linseed oil.	1½ Painter.

For 100 square feet, Rupees 2-4.

Tarring Palmyra Rafters, 1 Coat.

2 Measures of tar.	½ Man cooly.

For 100 square feet, Annas 9.

Tarring Palmyra Rafters, 2 Coats.

3 Measures of tar.	1 Man cooly.

For 100 square feet, Annas 14.

Milk white paint, 1 Coat.

$\frac{5}{8}$ Viss of white lead.	$\frac{1}{8}$ Grinder.
$\frac{1}{4}$ Measure of milk.	$\frac{1}{2}$ Painter.
$2\frac{1}{2}$ Pollums of gum.	Sundries.

For 100 square feet, Annas 11-3.

Milk white paint, 2 Coats.

1 Viss of white lead.	1 Grinder.
$\frac{1}{2}$ Measure of milk.	1 Painter.
$3\frac{3}{4}$ Pollums of gum.	Sundries.

For 100 square feet, Rupee 1-4.

Milk white paint, 3 Coats.

$1\frac{1}{2}$ Viss of white lead.	$1\frac{1}{8}$ Grinder.
$\frac{1}{2}$ Measure of milk.	$1\frac{1}{2}$ Painter.
$3\frac{3}{4}$ Pollums of gum.	$\frac{1}{2}$ Measure of wood oil.

For 100 square feet, Rupees 2-2.

Mixture for ceiling cloths or Arsenate Potash.

1 Ounce of arsenic.	$\frac{1}{2}$ Bricklayer.
6 Drachms of carbonate of potash.	$\frac{1}{4}$ Man cooly.
5 Pollums of country soap.	$\frac{1}{2}$ Boy.
	Sundries.

For 100 square feet, Annas 8-8$\frac{3}{4}$.

Painter and Glazier.

One pound of paint will cover about four superficial yards the first coat, and about six yards each additional coat.

About one pound of putty for stopping will be required for every twenty yards.

One gallon of tar and one pound of pitch will cover about twelve yards superficial the first coat, and about seventeen yards each additional coat.

According to the London Oil and Colour Company's Price List.

1 Gallon of	Priming Colour	will cover	50	superficial yards.
"	White Zinc ...	"	50	"
"	White Paint ...	"	44	"
"	Lead Colour ...	"	50	"
"	Black Paint ...	"	50	"
"	Stone Colour ...	"	44	"
"	Yellow Paint ...	"	44	"
"	Blue Colour ...	"	45	"
"	Green Paint ...	"	45	"
"	Bright Emerald Green	"	25	"
"	Bronze Green ...	"	45	"

Hubbuck's Pale Boiled Linseed Oil.

For many years Hubbuck & Son have made this *Oil much paler in colour* than Raw Linseed Oil. It is the most desirable improvement ever made, and invaluable to all who require beautiful and durable Paints.

By their Patent process of Boiling Linseed Oil, all the fatty matter—which renders the Paint non-drying and sticky—is extracted; this makes the Paint dry quickly, with a perfectly hard and smooth surface, and consequently much more durable.

Hubbuck's Pale Boiled Oil does not discolour White and other delicate colours, and will not blister like the old fashioned Dark or Black Boiled Oil.

Directions for using Hubbuck's Patent White Zinc Paint.

The Fronts of Houses coated with this Paint will not discolor in the London Atmosphere, or in the neighbourhood of Gas and Chemical Works.

Quantity.—Experience has shewn that 1 cwt. Zinc Paint and 3 gallons of Oil, will cover as much surface as $1\frac{1}{2}$ cwt. of White Lead and 6 gallons of Oil.

From the smoothness of this paint it should not be mixed so thin as White Lead, and the common coarse paints. The best effect is produced by mixing it as stiff as possible.

Mixing.—For outside work, with 1 cwt. of Zinc Paint mix 6 lbs. of Driers and the usual staining colors, then add $2\frac{3}{4}$ gallons Boiled Linseed Oil and $\frac{1}{2}$ gallon Turpentine.

For inside work, to 1 cwt. of Zinc Paint add 6 lbs. of Driers, and 2 gallons of Hubbuck's Pale Boiled Linseed Oil, and 1 gallon of Turpentine. The less Turpentine used the more durable the Paint.

Flatting.—Use $2\frac{1}{2}$ gallons of Turpentine and $\frac{1}{2}$ gallon Raw Linseed Oil, to 1 cwt. of Zinc Paint, and it will be a perfect flat in a few days.

Zinc Driers are made expressly for this paint, 6 lbs. being ample for 1 cwt. of color. Patent Driers, Red Lead, Litharge, Sugar Lead, and all preparations containing Lead, turn Black with Gases or noxious vapors, and injure the colors they are mixed with.

Staining.—Indigo, Verdigris, Yellow Oker, Venetian Red, Umber, Ivory Black, and the other permanent colors are best.

Putty, for stopping, is made by stiffening the Paint with whiting. For Engine-joints it is the hardest and most lasting cement, and from its greater bulk, cheaper than White Lead.

Observe that the old Paint on iron or wood is well scraped and rubbed down and free from salt or damp; and to facilitate its galvanizing effect on iron, be careful that the first coat is well rubbed in.

Keeping.—To prevent the Paint from skinning after the casks are opened, cover it with oil never with water.

Fluxes for Soldering.

Tinned Iron—Resin or Chloride of Zinc.
Copper and Brass—Sal ammoniac or Chloride of Zinc.
Zinc—Chloride of Zinc.
Lead—Resin.

Solders.

For Lead—Tin, 1 part; Lead, 2 parts.
For Tin—Pewter, 4 parts; Tin, 1; Bismuth, 1.
For Pewter—Bismuth, 2 parts; Lead, 1; Tin, 2.
For Brass—Brass, 2 parts; Zinc, 1.
For Gold—Gold, 12 parts; Silver, 2; Copper, 4.
For Silver—Silver, 5 parts; Brass, 6; Zinc, 2.
Hard Solder—Copper, 2 parts; Zinc, 1.
Soft Solder—Tin, 2 parts; Lead, 1.

The following are the cart-loads (single) carried at the Presidency Town, but the quantities must necessarily vary in Districts where the Roads are not so good.

Material.	Quantity per Cart.
Wall Bricks	400
Arch Bricks	400
Terrace Bricks	1,000
Terrace Tiles	1,000
Square Tiles	1,000
Pan Tiles	1,000
Square Bricks, 6 inches	400
Do. 8 do.	200
Do. 10 do.	100
Do. 12 do.	60
Laterite stone-jelly	Parahs 8
Gravel	,, 8
Brick-jelly	,, 7
Sand	,, 7
Chunam, slaked	,, 20
Shells	,, 14
Granite stone	Cubic ft. 6
Laterite stone	,, 9

The parah measure, given in the foregoing Table and Data, is that in general use now in Madras, viz., 24″ by 24″ by 7″ = 4,032 Cubic inches.

In the road department, a cart-load is 15 cubic feet of road material.

40 m.m.

CARTAGE.

The daily hire of a cart being 12 Annas, the number of trips per day, and the price per cart-load, will be as follows :—

Distance.	Number of Trips.	Cost of a cart-load. Annas.	Pice.
100 yards to ½ a mile.	10	1	2-4
½ a mile ,, ¾ ,,	8	1	6
¾ ,, ,, 1 ,,	6	2	0
1 ,, ,, 1¼ ,,	5	2	4-8
1¼ ,, ,, 1¾ ,,	4	3	0
1¾ ,, ,, 2½ ,,	3	4	0
2½ ,, ,, 3½ ,,	2	6	0
3½ ,, ,, 4½ ,,	1½	8	0
4½ ,, ,, 5¼ ,,	1¼	9	7-2
5¼ ,, ,, 8 ,,	1	12	0

When the daily hire of a cart exceeds 12 Annas, the price of a load must be increased in proportion.

24 cubic feet of sand, 18 cubic feet of earth, or 17 cubic feet of clay, make 1 ton. A cubic yard of solid gravel or earth before digging becomes 1½ cubic yards when dug. A ton of granite is 13½ cubic feet, or half a cubic yard. A cubic foot of granite weighs 166 pounds ; of brick earth 125 pounds ; of bar iron 486 lbs. ; of teakwood 50 pounds ; of water 62½ pounds.

EARTHWORK.

Rates originally paid for earthwork, (in repairing tank banks, &c.,) in the Arcot and Chingleput Districts.

Depth of excavation in yards.	Sand. Carried a distance of							Cotton Soil or deposit. Carried a distance of							Gravel or stony soil. Carried a distance of							Remarks.
	yards. 0	10	15	20	30	40	50	0	10	15	20	30	40	50	0	10	15	20	30	40	50	
	Pice.																					
½	2½	3½	4	5	6	7	8	4½	5½	6½	7½	8½	9½	10½	6	8	8½	9	10	11	12	Distances are reckoned from the middle of the pits to the top of the bank. When the tank bank exceeds 2 yards in height, one pice per C. yard is given for each yard of height in excess of 2 yards. A further addition of one pice per C. yard is made for beating the earth. Higher rates for hard soil are allowed on the authority of the civil engineer.
1	3	4	4½	5½	6½	7½	8½	5	6	7	8	9	10	11	8½	10½	11	12	13	14	15	
1½	3½	4½	5	6	7	8	9	5½	6½	7½	8½	9½	10½	11½	9½	11½	12	13	14	15	16	
2	4	5	5½	6½	7½	8½	9½	6	7	8	9	10	11	12	10½	12½	13	14	15	16	17	
2½	4½	5½	6	7	8	9	10	6½	7½	8½	9½	10½	11½	12½	11½	13½	14	15	16	17	18	
3	5	6	6½	7½	8½	9½	10½	7	8	9	10	11	12	13	12½	14½	15	16	17	18	19	
3½	5½	6½	7	8	9	10	11	7½	8½	9½	10½	11½	12½	13½	13½	15½	16	17	18	19	20	
4	6	7	7½	8½	9½	10½	11½	8	9	10	11	12	13	14	14	16½	17	18	19	20	21	

The following are the cart-loads (single) carried at the Presidency Town, but the quantities must necessarily vary in Districts where the Roads are not so good.

MATERIAL.	QUANTITY PER CART.
Wall Bricks	400
Arch Bricks	400
Terrace Bricks	1,000
Terrace Tiles	1,000
Square Tiles	1,000
Pan Tiles	1,000
Square Bricks, 6 inches	400
Do. 8 do.	200
Do. 10 do.	100
Do. 12 do.	60
Laterite stone-jelly	Parahs 8
Gravel	„ 8
Brick-jelly	„ 7
Sand	„ 7
Chunam, slaked	„ 20
Shells	„ 14
Granite stone	Cubic ft. 6
Laterite stone	„ 9

The parah measure, given in the foregoing Table and Data, is that in general use now in Madras, viz., 24″ by 24″ by 7″ = 4,032 Cubic inches.

In the road department, a cart-load is 15 cubic feet of road material.

40 m.m.

CARTAGE.

The daily hire of a cart being 12 Annas, the number of trips per day, and the price per cart-load, will be as follows :—

DISTANCE.	Number of Trips.	Cost of a cart-load. Annas.	Pice.
100 yards to ½ a mile.	10	1	2·4
½ a mile „ ¾ „	8	1	6
¾ „ „ 1 „	6	2	0
1 „ „ 1¼ „	5	2	4·8
1¼ „ „ 1¾ „	4	3	0
1¾ „ „ 2½ „	3	4	0
2½ „ „ 3½ „	2	6	0
3½ „ „ 4½ „	1½	8	0
4½ „ „ 5¼ „	1¼	9	7·2
5¼ „ „ 8 „	1	12	0

When the daily hire of a cart exceeds 12 Annas, the price of a load must be increased in proportion.

24 cubic feet of sand, 18 cubic feet of earth, or 17 cubic feet of clay, make 1 ton. A cubic yard of solid gravel or earth before digging becomes 1½ cubic yards when dug. A ton of granite is 13½ cubic feet, or half a cubic yard. A cubic foot of granite weighs 166 pounds ; of brick earth 125 pounds ; of bar iron 486 lbs. ; of teakwood 50 pounds ; of water 62½ pounds.

EARTHWORK.

Rates originally paid for earthwork, (in repairing tank banks, &c.,) in the Arcot and Chingleput Districts.

Depth of excavation in yards.	Sand. Carried a distance of							Cotton Soil or deposit. Carried a distance of							Gravel or stony soil. Carried a distance of							Remarks.
	yards. 0	10	15	20	30	40	50	0	10	15	20	30	40	50	0	10	15	20	30	40	50	
	Pice.																					
½	2½	3½	4	5	6	7	8	4½	5½	6½	7½	8½	9½	10½	6	8	8½	9	10	11	12	Distances are reckoned from the middle of the pits to the top of the bank. When the tank bank exceeds 2 yards in height, one pice per C. yard is given for each yard of height in excess of 2 yards. A further addition of one pice per C. yard is made for beating the earth. Higher rates for hard soil are allowed on the authority of the civil engineer.
1	3	4	4½	5½	6½	7½	8½	5	6	7	8	9	10	11	8½	10½	11	12	13	14	15	
1½	3½	4½	5	6	7	8	9	5½	6½	7½	8½	9½	10½	11½	9½	11½	12	13	14	15	16	
2	4	5	5½	6½	7½	8½	9½	6	7	8	9	10	11	12	10½	12½	13	14	15	16	17	
2½	4½	5½	6	7	8	9	10	6½	7½	8½	9½	10½	11½	12½	11½	13½	14	15	16	17	18	
3	5	6	6½	7½	8½	9½	10½	7	8	9	10	11	12	13	12½	14½	15	16	17	18	19	
3½	5½	6½	7	8	9	10	11	7½	8½	9½	10½	11½	12½	13½	13½	15½	16	17	18	19	20	
4	6	7	7½	8½	9½	10½	11½	8	9	10	11	12	13	14	14	16½	17	18	19	20	21	

No. 1685.

MYSORE PUBLIC WORKS DEPARTMENT,

CENTRAL OFFICE.

MEMORANDUM.

The want of Tables of scantling for beams and trusses, having been experienced in this department, the accompanying ones, applicable to the most generally useful of the indigenous Mysore timbers, are now by desire of the Officiating Chief Engineer, circulated for future adoption in all roof designs.

2. With timbers differing so much, in relative strength and elasticity, it would have been a tedious undertaking, to frame a set of Tables for each; a general and somewhat arbitrary classification has, therefore, been adopted which, within the limits assigned, will be found sufficiently accurate for all practical purposes. while at the same time allowing of one set of Tables answering for all.

3. From Table No. I, it will be observed that the classification has been determined, by the value of $E = \frac{L^3 W}{b d^3 \delta}$ in each case: Class No. I embracing all timbers, the value of E for which has been found by experiment, to range from 4,000 to 4,500: Class No. II, those ranging from 3,500 to 4,000: and Class No. III, from 3,000 to 3,500.

4. Although arbitrary, this is a sufficiently near approximation to the truth, as an increase or decrease of 500 in the value of E, is very nearly represented by the difference of the scantlings, assigned to the spans next above and below.

5. In using the Tables, first ascertain from No. I, to what class the timber belongs: if of the 1st Class, take out the required scantling directly opposite the given span, whether for terraced or pent roofing: if of the 2nd Class, take the scantling assigned to the next greatest span; and if of the 3rd Class, take that of the next greatest again.

6. Thus, if it be wished to ascertain, the correct scantling of a teakwood girder for a terraced roof, 20 feet span, the girders being placed at 10 feet from centre to centre, take out the scantling under a span of 21 feet in Table No. 3, which gives 16″ × 11½″. Were on the other hand, the timber Sumpengee, or Poon, the scantling would be 16½″ × 11¾″, or that under a span of 22 feet: the timber being 3rd Class.

7. It is not proposed here, to explain the nature of the experiments undertaken, for ascertaining the values of E for each timber, or give in detail the calculations made for fixing the scantlings required to sustain given weights of roofing, the following brief observations will, therefore, serve all present purposes.

8. The formula employed is the ordinary one $E = \frac{5}{8} . \frac{L^3 W}{b d^3 \delta}$ for rectangular beams; (L) being clear length of beam in feet between supports; (W) weight in lbs. of roofing spread equally along the beam, and determined by actual experiment for each description; (b) the breadth of beam in inches; (d) depth ditto, and (δ) the deflection assumed at ·05 of an inch for every foot in length.

Now if (a) be taken as the side of a square beam, and (w) be substituted for $\frac{5}{8}$ w, which is equivalent to the weight suspended from the centre, the above formula becomes $E = \frac{L^3 W}{a^4 \delta}$ hence $a = \sqrt[4]{\frac{L^3 W}{E \delta}}$.

The value of E being given in this equation, for any known timber, the side of a square beam capable of supporting the weight (w), with the deflection of $\frac{1}{20}''$ of an inch to the foot, is easily found by logarithms.

9. In calculating the present Tables, the value of E was taken throughout, as that given by the late Conductor Skinner, in his valuable work in India and Burman timbers, for Pegu teak, viz., 3,840; it will, therefore, be obvious, that sufficient provision has been made for ordinary purposes, by transferring this and other timbers of equal strength to the Second Class—or in other words assigning to them scantlings, which would suffice for timbers, the elasticity of which, is about 500 less than that ascertained by experiment.

10. Having found the value of (a) for a square beam, an assumption has to be made, to ascertain the dimensions of a corresponding rectangular one. By the practise in Upper India, the proportion of the breadth of a beam to its depth, has been taken as the side of square to its diagonal; hence $d = b\sqrt{2}$ and as $a^4 = b\, d^3 \therefore b = \frac{a}{\sqrt[4]{2\sqrt{2}}}$. Where b is assumed at $2\frac{1}{4}$ and 3 inches, the equations become $d = \sqrt[3]{\frac{a^4}{2\frac{1}{2}}}$ and $d = \sqrt[3]{\frac{a^4}{3}}$ respectively. All the Tables have been calculated from the above formulæ.

11. In conclusion, it may be observed that the useful Table No. 8, was calculated by Colonel Cunningham, when Chief Engineer of the N. W. Provinces.

R. H. SANKEY, Major, R.E.,
Assistant Chief Engineer
in Mysore.

BANGALORE,
5th November 1863.

TABLE

Particulars of the most generally useful timbers

TIMBERS.	Weight per C. ft. in lbs. Unseasoned.	Seasoned.	Class determined by value of $E = \frac{L^3 W}{b d^3 \delta}$	SIZES OF TIMBER AND LOCALITIES WHERE PROCURABLE CHIEFLY IN MYSORE AND COORG.
LAT. Inga Xylocarpa et Xylia dolabriformis. CAN. Jambai. TEL. Tangedu or Eryoovaloo.	68 to 74.	58.	The value of E ranging for these timbers from 4,000 to 4,500, they may be considered 1st Class.	Is scattered generally over the Nugur Jungles; understood to be in quantity about Hebba and Jaugur but not yet accessible; also found to some extent and of moderate size in the Kankuncottah, Iynoor Maureegoody and Goondul Jungles of Astagram.
LAT. Dalbergia latifolia. CAN. Biti. TEL. Yeroogoodoo.	58 to 62.	48.		The Biti is common throughout the Nugur Jungles. Beams to a limited extent are also procurable from the Jungles on the Mercara—Coadlipett road, Coorg, and at Fraserpett, and Tittamutty. Found at Munzerabad but not accessible. Pretty abundant in the Kankuncottah, Iynoor Maureegoody and Goondul Jungles of Astagram—less so in Periapatam.
LAT. Terminalia Coriacea. CAN. Mutti. TEL. Nalla Maddi.	75 to 80.	55 to 60.		A large quantity of this timber is to be found between Mundigudda, Yedhully, and Luckwallee in Nugur, also at Tittamutty, and on Mercara,—Coadlipett road in Coorg. Procurable of smaller size at Fraserpett. Found in Munzerabad but not accessible. Pretty abundant in the Kankuncottah, Heggadaven cottah, Iynoor Maureegoody, and Bandipore Jungles, also in those of Nunjungode.
LAT. Ptero-carpus Marsupium. CAN. Honay. TEL. Yegis.	65 to 70.	56.		Timber pretty abundant in the Nugur Jungles, procurable also of large size at Tittamutty and on Mercara,—Coadlipett road in Coorg; also of smaller size at Fraserpett, at Kankanhully in Bangalore. Found at Munzerabad, and in the several Jungles of the Astagram Division abovementioned.
LAT. Lagerstroemia Microcarpa. CAN. Nundi. TEL. Ventakoo.	50 to 54.	38 to 41.	E Ranging in these timbers from 3,500 to 4,000, they may be considered 2nd Class.	One of the commonest Jungle timbers in Nugur: a small supply procurable from the hills west of Shimogah. In Coorg it is procurable of large size on the Periambadi Ghaut, Tittamutty and on the Mercara Coadlipett road; also of smaller size at Fraserpett and on the Sumpunghee Ghaut. Found at Munzerabad, also to some extent at Cabbinally, Bissly, and Cissly Ghauts.
LAT. Artocarpus Hirsuta. CAN. Kedhalsna. TEL. ——	48 to 50.	36 to 40.		The wild "Jack" is found in the Nugur forests, also of moderate size at the localities abovementioned in Coorg. Found at Kempkull Munzerabad Ghaut, Kanginary Jungle, Bissly Ghaut, and Cissly Ghaut; pretty abundant and of good size.
LAT. Accasia Speciosa. CAN. Baughi or Vaghi. TEL. Dirisana.	—	50.		Found in the Nugur forests, and about Woority, and other places in Coorg. Procurable of large size and pretty abundant in the Munzerabad, and Bailoor Talook Jungles.
LAT. Tectona Grandis. CAN. Sagwan. TEL. Teka.	55 to 60.	37 to 45.		Teak of large size is found at base of the Bababoodens, 15 miles from bank of River at Luckwallee in Nugur. Procurable in quantity, and of good size in the Kankancottah, and Iynoor Maureegoody Jungles of Astagram.
LAT. Calophyllum bracteatum, Bunnamii et Angustifolia. CAN. Kooval. TEL. Ponna.	50 to 60.	41 to 45.	These timbers may be considered 3rd Class the value of E Ranging from 3,000 to 4,500.	Procurable to any extent, and of the largest size, on the Periambadi Ghaut in Coorg. Found at Munzerabad, also in the Kanginary Jungle, Bissly Ghaut.
LAT. Michelia Champaca. CAN. Sampangi. TEL. ——	56 to 58.	42.		Procurable in Nugur, also of moderate size in the localities abovementioned in Coorg; found at Munzerabad. It is also to be had in fair quantity and of good size in the abovementioned Jungles of Astagram, also in the Goneebed Jungle of Bailoor Talook.

No. I.

for employment in the Mysore Department Public Works.

DESCRIPTION OF GRAIN, COLOR, &c.

Wood of a dark red color fading to dark brown, heavy, close grained and brittle, an excellent wood for posts or sleepers; takes paint or varnish well, is not attacked by white ants.

This is the "Rose" or Blackwood of *Southern India, close grained, strong,* flexible and durable, of a deep purplish color. It is considered that 3 *years are required for seasoning.*

Wood of a reddish brown color, hard, heavy, durable under water, rather coarse in fibre and difficult to work. *In seasoning, the grain is apt* to open. Requires 12 to 15 months to season, is not touched by white ants. *Some consider it unsuited for* terracing from a liability to sag.

The Honay is a strong, durable, close grained timber, not very easily worked; light brown: is well adapted for all building purposes.

The wood is straight grained, easily worked and lasts well *if kept free* from alternations of dryness and damp; must be properly stored or will cast, shrinks ¼ of an inch to the foot in seasoning. The dark reddish brown wood is the best.

Better known as the Jungle Jack or "Anjelli" which is valued next to teak in ship building, the wood is strong, close grained, of a light yellowish brown color.

The wood is hard and durable, never warps or cracks, equals teak in strength, color light reddish brown, striped with dark colored veins.

Too well known to need description. The Malabar teak is superior to that of Burmah both in strength and durability, and that of Nugur is considered better than either. The bastard teak has apparently been far too much neglected; in shorter lengths it is equal to the other, and is as cheap again.

This is the well known "Poon Spar tree." *Though tough and elastic, it* is easy to saw and work up; holds a nail well, grain coarse and glossy and *color brown: lighter colored variety* tougher. It is not capable of enduring moisture for a long time.

Wood of a rich brown color, rather close grained, and finely mottled, polishes well, and is prized for furniture.

REMARKS.

This table gives *the characteristics of the most generally useful* timbers, for the Department in Mysore and Coorg, there are a great many others, however, which promise well, and should be employed as occasion offers: *of these the following may be specially mentioned:*

Synonyms. Botanical.	Synonyms. Canarese.	Classes corresponding to those in Table.	Localities.
Diospyros melanoxylon.	Baulay	Over standard of 1st Class	Nugur.
Conacarpus latifolia ...	Dundugas ...	Over standard of 1st Class	Kankanhully.
Vitex alata	Nowladdi ...	1st Class ...	Nugur.
Acasia odaratissima ...	Billawar ...	2nd Class ...	Nugur, Coorg, Kankanhully.
Bassia longifolia ...	Ippa	3rd Class ...	Nugur, Coorg, Kankanhully.
Nauclea cordifolia ...	Yettaga ...	3rd Class ...	Coorg, Kankanhully & Astagram Jungles.
Azedarachta Indica ...	Bavena ...	3rd Class ...	Kankanhully and Maidan Talooks.
Cedrela Toona	Gundagurghy	4th Class ...	Nugur
Vatica laciferra ...	Jaloda	Unclassed ...	Nugur, Kankanhully.
Ulmus integrifolia ...	Tupissee ...	Unclassed ...	Nugur.

Others such as Mussay, Honnaul, and Genseena Murrah, procurable in Nugur, are also well reported on for all work, they have not, however, been identified botanically, or subjected to experiment.

In purchasing timber it is hardly necessary to observe, that none *but thoroughly sound and seasoned logs should be selected; some* experience is required to judge whether timber is perfectly sound, but the condition as regards seasoning can be at once tested from the Table. *Where there is no tabulated weight for comparison,* Tredgold's rule will be found sufficiently accurate, viz., that seasoned timber should be less in weight by one-fifth, than the same when green.

As fresh cut logs require from 2 to 3 years to season by the ordinary method, and as the delay might prove inconvenient, the process may be expedited, by immersing the timber for some time in water or wet mud, and drying by exposure to the air, under shade. In stocking timber, the logs should be laid crossways one over the other, to secure a thorough perflation of air, the lowest log, moreover, being kept off the ground. Where from absolute necessity even *slightly* green timber has to be used, it ought on no account to be painted, as dry rot rapidly ensues.

There are various effective methods of preserving timber, when put up in a building, from the attacks of white ants and dry rot, such as steeping in sulphate of copper, (neela tota) chloride of zinc, and again by a composition of Gampir, dammer oil, and lime, &c., which should undoubtedly be resorted to in important structures, but which are not easily applied in practice to minor buildings. Ordinarily, therefore, it will suffice, if *first,* none but seasoned wood is used; *second,* if a free circulation of air, is secured round the ends of beams, where inserted into the walls; and *third,* if hurthal (yellow arsenic) is mixed with the mortar, (in the proportion of ½ lb. to 100 C. feet of masonry) in the immediate vicinity. For posts, charring the end inserted into the ground, will be found advantageous.

TABLE No. II.

Scantlings of joists for Terraced roofs.

Distance between points of Support,	Total length allowing for bearings.	Joists placed at 15 Inches from centre to centre.						Joists placed at 18 Inches from centre to centre.						Joists placed at 21 Inches from centre to centre.						Joists placed at 24 Inches from centre to centre.					
		Where the breadth bears the regulated proportion to the depth.			Where the breadth is made 3 Inches irrespective of the depth.			Where the breadth bears the regulated proportion to the depth.			Where the breadth is made 3 Inches irrespective of the depth.			Where the breadth bears the regulated proportion to the depth.			Where the breadth is made 3 Inches irrespective of the depth.			Where the breadth bears the regulated proportion to the depth.			Where the breadth is made 3 Inches irrespective of the depth.		
Feet.	Feet.	Depth in Inches.	Breadth in Inches.	Contents.	Depth in Inches.	Breadth in Inches.	Contents.	Depth in Inches.	Breadth in Inches.	Contents.	Depth in Inches.	Breadth in Inches.	Contents.	Depth in Inches.	Breadth in Inches.	Contents.	Depth in Inches.	Breadth in Inches.	Contents.	Depth in Inches.	Breadth in Inches.	Contents.	Depth in Inches.	Breadth in Inches.	Contents.
10	11½	5½	3¾	1·64	5¾	3	1·38	5¾	3¾	1·72	6¼	3	1·50	6	4	1·91	6½	3	1·56	6	4¼	2·04	6¾	3	1·62
11	12½	6	4¼	2·21	6½	3	1·69	6¼	4¼	2·30	6¾	3	1·76	6½	4½	2·53	7¼	3	1·89	9½	4¾	2·68	7½	3	1·95
12	13½	6½	4½	2·74	7	3	1·97	6½	4½	2·74	7¼	3	2·04	6¾	4¾	3·00	7¾	3	2·18	7	5	3·27	8	3	2·25
13	14½	6¾	4¾	3·23	7½	3	2·26	7	4¾	3·34	8	3	2·41	7¼	5	3·65	8½	3	2·56	7½	5¼	3·96	8¾	3	2·64
14	15½	7	5	3·76	8	3	2·58	7¼	5¼	4·09	8½	3	2·74	7½	5¼	4·24	9	3	2·90	7¾	5½	4·59	9½	3	3·06
15	17	7¼	5¼	4·48	8½	3	3	7¾	5½	5·02	9¼	3	3·27	8	5½	5·19	9¾	3	3·27	8¼	5¾	5·60	10¼	3	3·62
16	18	7½	5½	5·17	9¼	3	3·46	8	5¾	5·75	9¾	3	3·65	8¼	5¾	5·93	10¼	3	3·84	8½	6	6·37	10¾	3	4·03
17	19	8	5¾	6·07	9¾	3	3·86	8½	6	6·72	10½	3	4·15	8¾	6	6·93	11	3	4·35	9	6¼	7·42	11½	3	4·55
18	20	8¼	6	6·88	10¼	3	4·27	8¾	6¼	7·60	11	2	4·58	9	6¼	7·81	11½	3	4·79	9¼	6½	8·36	12	3	5·00
19	21	8¾	6	7·66	11	3	4·81	9¼	6½	8·77	11¾	3	5·13	9½	6½	9·01	12½	3	5·47	9¾	6¾	9·61	12¾	3	5·57
20	22½	9	6¼	8·79	11½	3	5·38	9½	6¾	10·03	12¼	3	5·74	10	6¾	10·55	12¾	3	5 97	10¼	7	11·20	13½	3	6·32
21	23½	9½	6½	10·08	12¼	3	5·99	10	7	11·41	13	3	6·36	10½	7	11·98	13½	3	6·60	10¾	7¼	12·71	14¼	3	6·97
22	24½	9¾	6¾	11·21	12¾	3	6·50	10¼	7	12·19	13½	3	6·89	10¾	7½	13·72	14¼	3	7·26	11	7¾	14·51	14¾	3	7·52
23	25½	10	7	12·38	13¼	3	7·17	10½	7¼	13·47	14¼	3	7·56	11	7¾	15·10	15	3	7·96	11¼	8	15·95	15¼	3	8·23
24	26½	10¼	7½	13·66	13¾	3	7·59	10¾	7½	14·81	14¾	3	8·14	11¼	8	15·57	15½	3	8·55	11½	8¼	17·43	16	3	8·83

REMARKS.

Ordinary terracing, which consists of one course of terrace bricks (each 5″ by 3″ by 1″) laid diagonally on edge in chunam, covered with 3 inches in thickness of well beaten brick concrete, and this again by two courses of flat tiles (each 5¼″ by 3½″ by 3¼″), and one course of square tiles (each 6″ by 6″ by ½″) the whole plastered in two coats, weighs 68lb per square foot.

Joists for this description of roofing, are generally spaced at 15 inches from centre to centre, and made 3 inches in thickness: sometimes however the terrace bricks are re-placed by boarding (in Northern India by thin stone slabs) on which the concrete is directly laid, and in such cases the joists may obviously be spaced at greater distances. Scantlings of suitable dimensions are, therefore, given in the Table; the practice of employing boards is not, however, advocated, as it is almost impossible to prevent dry rot. Buckled plates of sheet-iron would obviate the latter difficulty and might be employed in important Structures.

In order to obtain proper slopes on the upper roof surface for the discharge of rain water, the common practice of thickening the concrete in the centre by 2 or 3 inches, is manifestly wrong, as adding weight at the weakest point of the beam or joists; the requisite slope can easily be obtained by either raising slightly one end of the beam, or if it is wished to discharge on both sides from the centre, by nailing battens on the top about 3 inches thick in the centre, and sloping off to nothing on either side, or again by cambering the joists themselves. The roof may also with great advantage be lightened in the centre by reducing the thickness of the concrete to 1 or 1½ inches.

TABLE No. III.

Girders or beams for terraced roofs.

Distance in feet between points of support.	Total length in feet allowing for bearings.	Girders placed at 5 feet from centre to centre.			Girders placed at 10 feet from centre to centre.		
		Depth in Inches.	Breadth in Inches.	Contents C. Feet.	Depth in Inches.	Breadth in Inches.	Contents C. Feet.
14	16	9¾	7	7·58	11¾	8½	11·09
15	17	10½	7¼	8·98	12½	9	13·28
16	18	10¾	7¾	10·41	13	9¼	15·03
17	19½	11½	8	12·46	13¾	9¾	18·14
18	20½	11¾	8¼	13·80	14¼	10	20·27
19	21½	12½	8¾	16 32	15	10½	23·51
20	22½	12¾	9	17·93	15½	11	26·64
1	23½	13½	9½	20·93	16	11½	30·03
22	24½	13¾	9¾	22·79	16½	11¾	32·98
23	25½	14¼	10	25·23	17	12¼	36·87
24	26½	14½	10¼	27·34	17½	12½	40·25
25	27½	15	10¾	30·78	18¼	13	45·30
26	28½	15½	11	33·64	18¾	13¼	49·17
27	29½	16	11½	37 69	19¼	13¾	54·18
28	30½	16½	11¾	41·06	19¾	14	58·55

REMARKS.

As this description of roof necessitates the employment of joists, laid transversely over the beams, the weight of the former is here taken into account. The joists *in either case, unless boarding* be used, will be placed at 15 inches from centre to centre, and where the beams are 5 feet apart, they may measure in section 3½ inches square; where 10 feet, 6″ × 4″. The slope of the roof in this arrangement is obtained either by *slightly raising one* end of the beams, by cambering them or nailing battens as mentioned in the remarks in the foregoing Table. In Upper India, girders or beams placed at 3 feet from centre to centre, have been almost exclusively *employed for terraced roofs*, the interval between these beams, being in some cases spanned by small joists (burgahs) 3 inches square in section, covered with two courses of tiles, and 4 inches of concrete; in others, small half brick segmental arches, with *4 inches rise*, are turned *from* beam to beam, instead of employing burgahs. The weights of these description of terracing, being respectively 75 and 91 lbs. per superficial foot, the beams require to be of greater scantling than shown in the Table: those of for 1 and 2 feet, greater spans would suffice. The precautions regarding the employment of sound timber, given in the Remarks to Table No. I, are especially requisite with this description of roofing. 12 to 15 inches has been allowed here for the bearing at either end of the beam; this should be ample if a wooden plate, or still better a stone slab of the same width, and from 2 to 2½ feet long, be placed below.

TABLE No. IV.

Dimensions of Rafters and Hips in couples for common tiled roofs.

Span of roof.	RAFTERS. (Spaced 18 Inches from centre to centre.) Length in feet with allowance for eaves.	Where the breadth bears the regulated proportion to the depth. Depth in Inches.	Breadth in Inches.	Contents in cubic feet and decimals.	Where the breadth is made 3 Inches irrespective of the depth. Depth in Inches.	Breadth in Inches.	Contents in cubic feet and decimals.	HIPS. Length in feet with allowance for eaves.	Where the breadth bears the regulated proportion to the depth. Depth in Inches.	Breadth in Inches.	Contents in cubic feet and decimals.	Where the breadth is made 3 Inches irrespective of the depth. Depth in Inches.	Breadth in Inches.	Contents in cubic feet and decimals.
10	8	3¼	2¼	·40	3	3	·50	10½	4½	3	·98	4¼	3	·92
12	9¼	3¾	2½	·60	3½	3	·67	12¼	5½	4	1·87	6	3	1·53
14	10½	4	2¾	·80	4	3	·87	13¼	6¼	4½	2·58	7	3	1·93
16	11¾	4¼	3¼	1·12	4½	3	1·10	15½	6¾	4¾	3·45	8	3	2·58
18	12	4½	3½	1·31	5	3	1·25	17	7½	5½	4·86	9¼	3	3·27
20	14	5	3½	1·70	5¼	3	1·53	18½	8¼	6	6·35	10¼	3	3·95
22	15¼	5½	3¾	2·18	5¾	3	1·82	20¼	9½	6¾	9·01	12	3	5·06
24	16½	5¾	4	2·63	6¼	3	2·14	21¾	10	7¼	10·95	13½	3	6·11
26	17¾	6¼	4¼	3·27	7	3	2·58	23¾	10¾	7¾	13·74	14½	3	7·17
28	18¾	6½	4½	3·80	7¼	3	2·83	25	11¼	8	15·62	15¾	3	8·20
30	20	6¾	4¾	4·45	7¾	3	3·22	26¼	12¼	8¾	19·53	17½	3	9·57

REMARKS.

By *span* in this Table is meant the clear width between the feet of the rafters. The scantlings are calculated to bear the usual reapers (2″×½″) one course of flat tiles and pot or pan tiles above, with the weight of the latter increased by saturation from rain. Up to 15 or 16 feet spans the Table will be found useful for couples placed at 18 inches from centre to centre, but above this the dimensions can be only usefully employed for rafters unsupported by struts and as such would only be employed for leans-to. For the dimensions of common and principal rafters for tiled roofs, see Tables Nos. V and VI. The length of rafters and hips here given equally, of course, apply to all roofs with a rise equal to one-third the span.

TABLE No. V.

Dimensions of Purlins and common Rafters for tiled roofs.

PURLINS.							COMMON RAFTERS. (PLACED AT 18 INCHES FROM CENTRE TO CENTRE.)						
		Where the depth bears the regulated proportion to the breadth.			Where breadth is equal depth.			Where the depth bears the regulated proportion to the breadth.			Where breadth is 2¼ Inches.		
Distances apart in feet from centre to centre.	Length in feet allowing for Seating.	Depth in Inches.	Breadth in Inches.	Contents in cubic feet and decimals.	Scantling in Inches if square in Section.	Contents in cubic feet and decimals.	Length in feet.	Depth in Inches.	Breadth in Inches.	Contents of each in cubic feet & decimals.	Depth in In. if made 2¼ In. thick.	Contents in cubic feet and decimals.	Quantity of timber employed in 100 square feet of roofing if purlins square in Section and common rafters 2¼ Inches thick be used. — Cubic feet and decimals.
3	11	6¼	4½	2·14	5¾	2·52	3	2	1½	·06	0	0	9·73
4	11	6½	4¾	2·35	6	2·75	4	3	2	·16	2¾	·19	10·
5	11	7	4¾	2·53	6¼	2·98	5	3½	2¼	·30	3½	·30	10·
6	11	7¼	5	2·76	6½	3·22	6	4	2¾	·45	4	·41	10·36
7	11	7½	5	2·86	6¾	3·48	7	4½	3	·65	4¾	·57	10·4
8	11	7½	5¼	3·00	7	3·74	8	4¾	3¼	·85	5¼	·73	10·6
9	11	7¾	5½	3·10	7¼	4·01	9	5¼	3¾	1·22	6	·93	10·7
10	11	8	5¾	3·36	7½	4·29	10	5½	4	1·00	6½	1·12	11·76

REMARKS.

The trusses being assumed at 10 feet from centre to centre it follows that the purlins will all be of the same length. That *given in the Table allows 9 inches for seat*ing at either end, wherever practicable the purlin should, however, be long enough, to extend over 3 trusses, as there will thus be less chance of it sagging. A square section should also be preferred to rectangular.

The common rafters are all here assumed, at the exact length of their bearings from centre to centre of the purlins; in practically applying this Table to roofs, an addition of 18 inches must be made to the total length of rafter, to allow for the projection of the eaves.

It is clear from the last column in the Table, that the least quantity of timber is employed, by placing the purlins at 3 feet from centre to centre, but as the most stable position for the latter, is immediately over the junction of the strut, with the principal rafter of the supporting truss, it will be best in ordinary cases to disregard; the slight advantage gained in quantity and place the purlin correctly.

TABLE No. VI.

Dimension of trusses for common tiled roofs.

Span of roof in feet.	Principal Rafters (Each.) Length in feet with allowance for framing.	Principal Rafters (Each.) Depth in Inches.	Principal Rafters (Each.) Breadth in Inches.	Principal Rafters (Each.) Contents in cubic feet and decimals.	Tie Beams. Length in feet with allowance for framing.	Tie Beams. Depth in Inches.	Tie Beams. Breadth in Inches.	Tie Beams. Contents in cubic feet and decimals.	King Posts. Length in feet with allowance for framing.	King Posts. Depth in Inches.	King Posts. Breadth in Inches.	King Posts. Contents in cubic feet and decimals.	Struts (Each.) Length in feet with allowance for framing.	Struts (Each.) Depth in Inches.	Struts (Each.) Breadth in Inches.	Struts (Each.) Contents in cubic feet and decimals.	Total content of truss in cubic feet and decimals.
16	10¾	4½	3¼	1·09	17½	5	3¼	196	6	3	3¼	·40	5	3	3¼	·33	5·20
17	10¾	4¾	3½	1·24	18½	5	3½	2·24	6½	3	3½	·47	5¼	3	3½	·38	5·95
18	11	4¾	3½	1·26	19½	5	3½	2·36	6¾	3	3½	·49	5½	3	3½	·40	6·17
19	12	5	3½	1·45	20½	6	3½	2·98	7	3	3½	·51	5¾	3	3½	·41	7·21
20	13	5¼	3¾	1·77	21½	6	3¾	3·35	7½	4	3¾	·78	6	4	3¾	·62	8·81
21	13¾	5½	4	2·10	23	6	4	3·83	7¾	4	4	·85	6½	4	4	·72	10·32
22	14½	5¾	4	2·31	24	7	4	4·66	8	4	4	·88	6¾	4	4	·75	11·66
23	15¼	5¾	4¼	2·58	25	7	4¼	5·16	8½	4	4¼	1·00	7	4	4¼	·82	12·96
24	15¾	6	4¼	2·78	26	7	4¼	5·37	8¾	4	4¼	1·03	7¼	4	4¼	·85	13·66
25	16½	6¼	4¼	3·04	27	8	4¼	6·37	9	4	4¼	1·06	7¾	4	4¼	·91	15·33
26	17	6¼	4½	3·32	28	8	4½	7·00	9½	4	4½	1·18	8	4	4½	1·00	16·82
27	17½	6½	4½	3·55	29	8	4½	7·25	9¾	4	4½	1·21	8¼	4	4½	1·03	17·62
28	18	6¾	4¾	4·00	30	9	4¾	8·96	10	4	4¾	1·31	8½	4	4¾	1·12	20·53
29	18¾	7	5¾	4·32	31	9	4¾	9·23	10½	4	4¾	1·38	8¾	4	4¾	1·15	21·51
30	19¼	7	5	4·67	32	9	5	9·50	10¾	5	5	1·86	9	5	5	1·56	23·82
31	20¼	7¼	5	5·09	33½	9	5	10·00	11	5	5	1·90	9½	5	5	1·64	25·36
32	20¾	7½	5¼	5·67	34½	9	5¼	11·32	11½	5	5¼	2·09	9¾	5	5¼	1·77	28·29
33	21½	7¾	5¼	6·07	35½	10	5¼	12·94	11¾	5	5¼	2·14	10	5	5¼	1·82	30·88
34	22	7¾	5½	6·51	36½	10	5½	13·96	12	5	5½	2·29	10¼	5	5½	1·95	33·17
35	22¾	8	5½	6·95	37½	10	5½	14·32	12½	5	5½	2·38	10¾	5	5½	2·05	34·70
36	23¼	8	5¾	7·42	38½	10	5¾	15·37	12¾	6	5¾	3·05	11	6	5¾	2·63	38·72
37	23¾	8¼	5¾	7·82	39½	11	5¾	17·34	13	6	5¾	3·11	11¼	6	5¾	2·69	41·47
38	24¼	8¼	6	8·33	40½	11	6	18·56	13½	6	6	3·37	11½	6	6	2·87	44·33
39	25	8½	6¼	9·22	41½	11	6¼	19·84	13¾	6	6¼	3·57	11¾	6	6¼	3·05	47·95
40	25½	8¾	6¼	9·68	42½	11	6¼	20·29	14	6	6¼	3·64	12	6	6¼	3·12	49·53

REMARKS.

This Table shows the dimensions and contents of trusses, placed 10 feet from centre to centre and calculated to bear a weight over all of 50lbs. to the square foot, which gives ample allowance for the weight of purlins, common rafters, reapers, also tiles when saturated with rain, &c. For dimensions of purlins, &c., see Table No. V.

In estimating the length of the *Principal rafters*, 12 inches extra has been allowed for framing in all spans, from 16 to 20 feet, 15 inches, in all from 20 to 30; and 18 inches, from 13 to 40 feet. For *tie beams* 18, 24 and 30 inches, are similarly added to the clear spans within same limits For *King posts*, 9 inches has been added in all cases.

Should it be desirable to substitute iron, for tie beams and kingposts, the following diameters in inches of round rod iron will answer.

	FOR ALL SPANS VARYING FROM					
	16 to 19 feet.	20 to 24 feet.	25 to 29 feet.	30 to 34 feet	35 to 39 feet.	40 feet.
Tie beams	¾	1	1¼	1½	1¾	2
King posts	½	¾	1	1	1¼	1¼

As "Bengal terracing" weighs about 45lbs. per square foot, irrespective of the weight of the burghas, &c., it would be advisable to take out always scantlings, for the next greater spans.

A description of terracing lately advocated, which consists of two courses of flat tiles, (12" X 12" X 1¾" burnt very hard) and plastered over, weighs only 32 lbs. per square foot :—Scantlings for the next less spans will be found sufficient for this. The rise of such roofs need not exceed ⅛th of the span.

For corrugated iron or zinc roofs, rafters 6" X 3" spaced 3 feet from centre to centre, with 3 purlins to each sheet, will be found to answer.

TABLE No. VII.

Scantlings of Bressummers for Verandahs in common tiled roofs.

Distances in feet between points of support, or from inside to inside of Verandah Pillars.	OUTSIDE BREADTHS OF VERANDAH.																					
	6 Feet.		7 Feet.		8 Feet.		9 Feet.		10 Feet.		11 Feet.		12 Feet.		13 Feet.		14 Feet.		15 Feet.		16 Feet.	
	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.
6	5	3½	5¼	3¾	5½	3¾	5½	4	5¾	4	5¾	4¼	6	4¼	6	4½	6¼	4½	6¼	4½	6½	4½
7	5½	4	6¼	4¼	6	4½	6¼	4½	6½	4½	6½	4¾	6¾	4¾	6¾	5	7	5	7¼	5	7¼	5¼
8	6¼	4½	6½	4½	6¾	4¾	6¾	5	7	5	7	5¼	7¼	5¼	7¼	5½	7½	5½	7¾	5½	8	5½
9	6¾	5	7	5	7¼	5¼	7½	5½	7¾	5½	8	5¾	8¼	5¾	8¼	6	8½	6	8½	6	8¾	6
10	7¼	5¼	7½	5½	8	5½	8	5¾	8¼	6	8½	6¼	8¾	6¼	8¾	6½	9	6½	9	6½	9¼	6½
11	7¾	5¾	8	6	8¼	6¼	8½	6¼	8¾	6½	9	6¾	9½	6¾	9½	7	9¾	7	9¾	7	10	7
12	8½	6	8¾	6½	9	6½	9¼	6¾	9½	6¾	9¾	7	10	7	10	7¼	10¼	7¼	10½	7½	10¾	7½
13	9	6½	9¼	6½	9½	6¾	9¾	7	10	7¼	10½	7½	10¾	7½	10¾	7¾	11	7¾	11¼	8	11½	8
14	9½	6¾	9¾	7	10	7¼	10¼	7½	10½	7½	10¾	8	11¼	8	11¼	8¼	11½	8¼	11¾	8½	12	8½
15	10	7	10¼	7½	10½	7¾	10½	8	11	8	11½	8½	12	8½	12¼	8¾	12½	8¾	12½	9	12½	9¼
16	10½	7½	10¾	7¾	11	8	11¼	8¼	11½	8½	12	8¾	12½	9	12½	9¼	12¾	9¼	12¾	9½	13	9½

TABLE No. VIII.

For calculating the Cubic Content in feet of Round or Unsquared Timbers according to the Rule in common use:

VIZ.—SQUARE OF ¼ GIRTH X LENGTH = CONTENT.

1 Quarter Girth.

¼ Girth. Ft.	Ins.	0. Ft.	¼ Ft.	½ Ft.	¾ Ft.	¼ Girth. Ft.	Ins.	0. Ft.	¼ Ft.	½ Ft.	¾ Ft.
0	0					2	0	4·000	4·084	4·166	4·252
	1	·007	·011	·016	·021		1	4·339	4·427	4·515	4·605
	2	·028	·035	·043	·052		2	4·696	4·785	4·875	4·968
	3	·062	·073	·085	·097		3	5·062	5·157	5·252	5·347
	4	·111	·125	·141	·157		4	5·443	5·541	5·641	5·741
	5	·174	·191	·210	·230		5	5·842	5·941	6·042	6·145
	6	·250	·271	·293	·316		6	6·250	6·355	6·462	6·566
	7	·340	·365	·391	·417		7	6·672	6·781	6·891	7·001
	8	·444	·473	·503	·532		8	7·109	7·222	7·336	7·453
	9	·562	·594	·627	·660		9	7·562	7·678	7·794	7·909
	10	·694	·729	·765	·803		10	8·027	8·146	8·266	8·386
	11	·841	·880	·918	·958		11	8·504	8·628	8·751	8·875
1	0	1·000	1·042	1·085	1·129	3	0	9·000	9·126	9·251	9·376
	1	1·173	1·219	1·266	1·313		1	9·506	9·634	9·766	9·899
	2	1·361	1·409	1·459	1·510		2	10·032	10·160	10·292	10·426
	3	1·562	1·615	1·669	1·722		3	10·562	10·699	10·837	10·973
	4	1·777	1·833	1·891	1·949		4	11·111	11·249	11·391	11·533
	5	2·008	2·066	2·126	2·187		5	11·673	11·816	11·960	12·105
	6	2·250	2·313	2·377	2·441		6	12·250	12·397	12·544	12·691
	7	2·506	2·573	2·641	2·709		7	12·840	12·989	13·141	13·293
	8	2·778	2·848	2·921	2·991		8	13·445	13·598	13·758	13·909
	9	3·062	3·136	3·211	3·316		9	14·062	14·220	14·377	14·535
	10	3·360	3·437	3·560	3·594		10	14·694	14·855	15·016	15·180
	11	3·671	3·760	3·834	3·916		11	15·340	15·504	15·668	15·834
2	0	4·000	4·084	4·166	4·252	4	0	16·000	16·166	16·338	16·503

EXPLANATION.

Table I. Gives the Squares or Sectional areas of any Quarter Girth from 1 inch up to 4 feet, by ¼ inches. The numbers, therefore, are only required to be multiplied by the length to give the content.

Example. Required the Cubic content of a Log of Timber the mean Girth of which is 6 feet 7 inches, and Length 35 feet.

¼ Girth = 1 foot 7¾ inches.

The Sectional area of which from Table I is found to be 2·709, and 2·709 X 35 ft. = 94·815 cubic feet, the content of Log.

The following Tables will be of use when the ¼ Girth is given in feet and decimals of a foot

Tables for Converting

Inches into Decimals of a Foot. and Decimals of a Foot into Inches.

Ins. and Frac.	0 Ft.	¼ Ft.	½ Ft.	¾ Ft.	Dec. Ft.	Inches.
0	0	·021	·042	·062	·025	·3
1	·083	·104	·125	·146	·050	·6
2	·167	·187	·208	·229	·075	·9
3	·250	·271	·292	·312	·1	1·2
4	·333	·354	·375	·396	·2	2·4
5	·417	·437	·458	·479	·3	3·6
6	·500	·521	·542	·563	·4	4·8
7	·583	·604	·625	·646	·5	6·0
8	·667	·688	·708	·730	·6	7·2
9	·750	·771	·792	·815	·7	8·4
10	·833	·854	·875	·896	·8	9·6
11	·917	·938	·958	·979	·9	10·8

Round Cast-Iron. The Weight of a Lineal Foot.						Round and Square Brass. The Weight of a Lineal Foot.					
Diam. in inches.	Weight in lbs.	Diam. in inches.	Weight in lbs.	Diam. in inches.	Weight in lbs.	Diam or Side in in.	Round in lbs.	Square in lbs.	Diam. or Side in in.	Round in lbs.	Square in lbs.
1	2·454	5½	74·245	10	245·437	1/16	·0112	·0142	1 5/16	4·933	6·281
1¼	3·835	5¾	81·148	10¼	257·863	1/8	·0447	·0570	1⅜	5·414	6·893
1½	5·522	6	88·357	10½	270·595	3/16	·1012	·1282	1 7/16	5·918	7·534
1¾	7·517	6¼	95·874	10¾	283·634	¼	·1790	·2279	1½	6·443	8·203
2	9·818	6½	103·697	11	296·979	5/16	·2796	·3560	1 9/16	6·991	8·901
2¼	12·425	6¾	111·827	11¼	310·632	⅜	·4047	·5127	1⅝	7·563	9·627
2½	15·340	7	120·264	11½	324·591	7/16	·5486	·6978	1 11/16	8·155	10·382
2¾	18·561	7¼	129·008	11¾	338·857	½	·7159	·9115	1¾	8·789	11·165
3	22·089	7½	138·059	12	353·430	9/16	·9060	1·154	1 13/16	9·407	11·977
3¼	25·924	7¾	147·416	13	414·789	⅝	1·118	1·424	1⅞	10·117	12·817
3½	30·066	8	157·080	14	481·057	11/16	1·353	1·723	1 15/16	10·799	13·686
3¾	34·515	8¼	167·051	15	552·234	¾	1·611	2·051	2	11·454	14·583
4	39·270	8½	177·329	16	628·320	13/16	1·891	2·407	2⅛	12·932	16·463
4¼	44·33	8¾	187·913	17	709·314	⅞	2·194	2·791	2¼	14·496	18·457
4½	49·701	9	198·804	18	795·217	15/16	2·529	3·204	2⅜	16·152	20·565
4¾	55·377	9¼	210·002	20	981·750	1	2·863	3·646	2½	17·896	22·786
5	61·359	9½	221·507	22	1187·917	1 1/16	3·233	4·116	2⅝	19·731	25·122
5¼	67·649	9¾	233·319	24	1413·720	1⅛	3·624	4·614	2¾	21·655	27·572
						1 3/16	4·038	5·141	2⅞	23·670	30·135
						1¼	4·474	5·697	3	25·771	32·813

THE WEIGHT OF WROUGHT IRON BOLT HEADS, NUTS AND WASHERS.

Diam. of Bolt.	Hexagon Heads and Nuts.	Square Heads and Nuts.	Round. Washers.
inches.	per pair.	per pair.	per pair.
¼	20 to a lb.	16 to a lb.	20 to a lb.
⅜	10 ,,	8⅓ ,,	10 ,,
½	5 ,,	4⅙ ,,	5 ,,
⅝	2¾ ,,	2½ ,,	3 ,,
¾	2 ,,	·56 lbs.	·63 lbs.
⅞	·77 lbs.	·88	·77
1	1·25	1·31	1·25
1⅛	1·75	2·10	1·75
1¼	2·13	2·56	2·25
1⅜	3·00	3·60	3·25
1½	3·75	4·42	4·25
1⅝	4·75	5·70	5·25
1¾	5·75	7·00	6·50
1⅞	7·27	8·72	8·00
2	8·75	10·50	9·60
2½	17·00	21·00	19·00
3	28·80	36·40	32·50

Round and Square Iron.

Weight of a Lineal Foot.

Diam. or Side in in.	Round in lbs.	Square in lbs.	Diam. or Side in in.	Round in lbs.	Square in lbs.
⅛	·041	·053	3⅝	34·761	44·258
¼	·165	·210	3¾	37·199	47·363
5/16	·258	·329	3⅞	39·720	50·573
⅜	·372	·474	4	42·324	53·889
7/16	·506	·645	4⅛	45·011	57·310
½	·661	·842	4¼	47·780	60·835
9/16	·837	1·066	4⅜	50·632	64·467
⅝	1·033	1·316	4½	53·567	68·203
11/16	1·250	1·592	4⅝	56·584	72·045
¾	1·488	1·895	4¾	59·684	75·992
13/16	1·746	2·223	4⅞	62·867	80·041
⅞	2·025	2·579	5	66·132	84·201
15/16	2·325	2·960	5⅛	69·480	88·464
1	2·645	3·368	5¼	72·910	92·832
1⅛	3·348	4·263	5⅜	76·424	97·305
1¼	4·133	5·263	5½	80·019	101·884
1⅜	5·001	6·368	5⅝	83·698	106·567
1½	5·952	7·578	5¾	87·459	111·356
1⅝	6·985	8·894	5⅞	91·303	116·251
1¾	8·101	10·315	6	95·230	121·250
1⅞	9·300	11·841	6¼	103·331	131·565
2	10·581	13·472	6½	111·763	142·300
2⅛	11·945	15·209	6¾	120·525	153·457
2¼	13·392	17·051	7	129·618	165·035
2⅜	14·921	18·998	7½	148·796	189·453
2½	16·533	21·050	8	169·297	215·556
2⅝	18·228	23·208	8½	191·121	243·352
2¾	20·205	25·471	9	214·267	272·812
2⅞	21·865	27·839	9½	238·736	303·967
3	23·807	30·312	10	264·527	336·806
3⅛	25·833	32·891	10½	291·641	371·328
3¼	27·941	35·575	11	320·078	407·535
3⅜	30·131	38·364	11½	349·837	445·425
3½	32·405	41·259	12	380·919	485·000

Sheet Iron.

Weight of a Superficial Foot.

B. W. Gauge.	Dec. of an inch.	Weight in lbs.	B. W. Gauge.	Dec. of an inch.	Weight in lbs.
00000 (½)	·500	20·208	16 (1/16)	·063	2·546
0000	·450	18·187	17	·055	2·223
000	·437	17·662	18	·048	1·940
00 (⅜)	·375	15·156	19	·042	1·697
0	·340	13·742	20	·035	1·415
1 (5/16)	·312	12·610	21	·033	1·334
2	·284	11·477	22	·029	1·172
3	·261	10·549	23	·028	1·132
3—4 (¼)	·250	10·104	24	·025	1·014
4	·239	9·660	25	·021	·849
5	·217	8·770	26	·020	·808
6	·208	8·407	27	·018	·727
7 (3/16)	·187	7·558	28	·015	·606
8	·166	6·709	29	·013	·525
9	·158	6·386	30	·012	·485
10	·137	5·537	31	·010	·404
11 (⅛)	·125	5·052	32	·009	·364
12	·109	4·405	33	·008	·323
13	·094	3·799	34	·007	·283
14	·080	3·233	35	·005	·202
15	·072	2·910	36	·004	·162

Hoop Iron.

Weight of 100 Lineal Feet.

B. W. Gauge.	Width in ins.	Weight in lbs.	B. W. Gauge.	Width in ins.	Weight in lbs.
11	3	126·302	15	1½	36·375
11	2¾	115·777	15	1⅜	33·344
12	2½	91·780	16	1¼	26·523
12	2	73·424	17	1⅛	20·840
13	2¼	71·234	18	1	16·167
13	2	63·319	19	⅞	12·378
13	1¾	55·405	20	¾	8·841
14	1¾	47·153	21	⅝	6·947
14	1½	40·417			

Corrugated Iron Roofing.

B. W. Gauge.	Size of Sheets.	Weight per Square.	No. of sup. feet per ton.
	ft. ft. ft. ft.	Cwts.	
16	6 X 2 to 8 X 3	3⅛	800
18	6 2 „ 8 3	2¼	1000
20	6 2 „ 8 3	1¾	1250
22	6 2 „ 7 2½	1½	1550
24	6 2 „ 7 2½	1¼	1880
26	6 2 „ 7 2½	1	2170

The Weight of a Superficial Foot of Plates of Various Metals.

Thickness in inches.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Brass.	Lead.	Zinc.	Thickness in inches.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1-16	2·526	2·344	2·552	2 891	2·734	3 708	2·344	1-16
1-8	5·052	4·687	5·104	5·781	5·469	7·417	4 687	1-8
3-16	7·578	7·031	7·656	8·672	8 203	11·125	7 031	3-16
¼	10·104	9 375	10 208	11 563	10·938	14·833	9 375	¼
5-16	12·630	11·719	12·760	14·453	13·672	18 542	11·719	5-16
3-8	15·156	14·062	15 312	17 344	16·406	22 250	14·062	3-8
7-16	17·682	16·406	17·865	20·234	19·141	25·958	16·406	7-16
½	20·208	18 750	20·417	23·125	21·875	29 667	18·750	½
9-16	22·734	21 094	22 969	26·016	24 609	33 375	21·094	9 16
5-8	25·260	23 437	25·521	28 906	27·344	37 083	23·437	5-8
11-16	27·786	25 781	28·073	31·797	30 078	40 792	25 781	11-16
¾	30·312	28 125	30 625	34 688	32·813	44·500	28·125	¾
13-16	32·839	30·469	33·177	37·578	35 547	48·208	30·469	13-16
7-8	35·365	32·812	35·729	40·469	38·281	51 917	32 812	7 8
15-16	37·891	35·156	38·281	43·359	41·016	55·625	35·156	15-16
1	40·417	37 500	40 833	46·250	43 750	59·333	37 500	1

Links reduced to Feet and Decimals (J. L. Gallot.)

Links.	Ft. Dec.	Links.	Ft. Dec.	Links.	Ft. Dec.
1	·66	36	23 76	71	46·86
2	1·32	37	24·42	72	47·52
3	1·98	38	25·08	73	48 18
4	2 64	39	25·74	74	48 84
5	3·30	40	26·40	75	49 50
6	3·96	41	27 06	76	50 16
7	4·62	42	27·72	77	50·82
8	5·28	43	28·38	78	51·48
9	5·94	44	29·04	79	52 14
10	6·60	45	29·70	80	52·80
11	7·26	46	30 36	81	53·46
12	7·92	47	31·02	82	54·12
13	8·58	48	31 68	83	54·78
14	9·24	49	32 34	84	55 44
15	9·90	50	33 00	85	56·10
16	10·56	51	33 66	86	56·76
17	11·22	52	34·32	87	57·42
18	11·88	53	34·98	88	58·08
19	12·54	54	35·64	89	58 74
20	13 20	55	36·30	90	59·40
21	13·86	56	36·96	91	60 06
22	14·52	57	37·62	92	60·72
23	15·18	58	38·28	93	61·38
24	15·84	59	38 94	94	62·04
25	16·50	60	39 60	95	62 70
26	17·16	61	40·26	96	63 36
27	17·82	62	40·92	97	64·02
28	18·48	63	41 58	98	64·68
29	19·14	64	42·24	99	65·34
30	19·80	65	42 90	100	66·00
31	20·46	66	43·56	200	132·00
32	21·12	67	44·22	300	198·00
33	21·78	68	44·88	400	264 00
34	22·44	69	45·54	500	396 00
35	23·10	70	46·20	600	330·00

Flat Bar Iron.—Weight of a Lineal Foot.

Width in In.	Thickness in inches.												Width in In.
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1/16	·0132	·0263	·0395	·0526	·0658	·0789	·0921	·1053	·1316	·1579	·1842	·2105	1/16
1/8	·0263	·0526	·0789	·1053	·1316	·1579	·1842	·2105	·2631	·3158	·3684	·4210	1/8
3/16	·0395	·0789	·1184	·1579	·1973	·2368	·2763	·3158	·3947	·4736	·5526	·6315	3/16
1/4	·0526	·1053	·1579	·2105	·2631	·3158	·3684	·4210	·5263	·6315	·7368	·8420	1/4
5/16	·0658	·1316	·1973	·2631	·3289	·3947	·4605	·5263	·6578	·7894	·9210	1·053	5/16
3/8	·0789	·1579	·2368	·3158	·3947	·4736	·5526	·6315	·7894	·9473	1·105	1·263	3/8
7/16	·0921	·1842	·2763	·3684	·4605	·5526	·6447	·7368	·9210	1·105	1·289	1·474	7/16
1/2	·1053	·2105	·3158	·4210	·5263	·6315	·7368	·8420	1·053	1·263	1·474	1·684	1/2
9/16	·1184	·2368	·3552	·4736	·5920	·7104	·8289	·9473	1·184	1·421	1·658	1·895	9/16
5/8	·1316	·2631	·3947	·5263	6578	·7894	·9210	1·053	1·316	1 579	1·842	2·105	5/8
11/16	·1447	·2894	·4342	·5789	·7236	·8683	1·013	1·158	1·447	1·737	2·026	2·316	11/16
3/4	·1579	·3158	·4736	·6315	·7894	·9473	1·105	1·263	1·579	1·895	2·210	2·526	3/4
13/16	·1710	·3421	·5131	·6841	·8552	1·026	1·197	1·368	1·710	2·052	2·394	2·737	13/16
7/8	·1842	·3684	·5526	·7368	·9210	1·105	1·289	1·474	1·842	2·210	2·579	2·947	7/8
15/16	·1973	·3947	·5920	·7894	·9867	1·184	1·381	1·579	1·973	2·368	2·763	3·158	15/16
1	·210	·421	·632	·842	1·053	1·263	1·474	1·684	2·105	2·526	2·947	3·368	1
1 1/8	·237	·474	·710	·947	1·184	1·421	1·658	1·895	2·368	2·842	3·315	3·789	1 1/8
1 1/4	·263	·526	·789	1·053	1 316	1·579	1·842	2·105	2·631	3 158	3·684	4·210	1 1/4
1 3/8	·289	·579	·868	1·158	1·447	1·737	2·026	2·316	2·894	3·473	4·052	4·631	1 3/8
1 1/2	·316	·632	·947	1·263	1·579	1·895	2·210	2·526	3·158	3·789	4·421	5·052	1 1/2
1 5/8	·342	·684	1·026	1·368	1·710	2·052	2·394	2·737	3 421	4·105	4·789	5·473	1 5/8
1 3/4	·368	·737	1·105	1·474	1·842	2·210	2·579	2 947	3·684	4·421	5·157	5·894	1 3/4
1 7/8	·395	·789	1·184	1·579	1·973	2·368	2·763	3·158	3·947	4·736	5·526	6·315	1 7/8
2	·421	·842	1·263	1·684	2·105	2·526	2·947	3·368	4·210	5·052	5·894	6·736	2
2 1/8	·447	·895	1·342	1·789	2·237	2·684	3·131	3·579	4·473	5·368	6·262	7·157	2 1/8
2 1/4	·474	·947	1·421	1·895	2·368	2 842	3·315	3·789	4·736	5·684	6·831	7·578	2 1/4
2 3/8	·500	·1000	1·500	2·000	2·500	3·000	3·500	4·000	4·999	5·999	6·999	7·999	2 3/8
2 1/2	·526	1·053	1·579	2·105	2·631	3·158	3·684	4·210	5·263	6·315	7·368	8·420	2 1/2
2 5/8	·553	1·105	1·658	2·210	2·763	3·315	3·868	4·421	5·526	6·631	7·736	8·841	2 5/8
2 3/4	·579	1·158	1·737	2·316	2·894	3·473	4·052	4·631	5·589	6·947	8·104	9·262	2 3/4
2 7/8	·605	1·210	1·816	2·421	3·026	3·631	4·236	4·842	6·052	7·262	8·473	9·683	2 7/8
3	·632	1·263	1·895	2·526	3 158	3·789	4·421	5·052	6·315	7·578	8·841	10·104	3
3 1/4	·684	1·368	2·052	2·737	3·421	4·105	4·789	5·473	6·841	8·210	9 578	10·946	3 1/4
3 1/2	·737	1·474	2 210	2·947	3·684	4·421	5·157	5·894	7·368	8·841	10·315	11·788	3 1/2
3 3/4	·789	1·579	2·368	3·158	3·947	4·736	5·526	6·315	7·894	9·473	11·051	12·630	3 3/4
4	·842	1·684	2·526	3·368	4·210	5·052	5·894	6·736	8·420	10·104	11·788	13·472	4
4 1/4	·895	1·789	2·684	3·579	4·473	5·368	6·262	7·157	8·946	10·736	12·525	14·314	4 1/4
4 1/2	·947	1·895	2·842	3·789	4·736	5·684	6 631	7·578	9·473	11·367	13·262	15·156	4 1/2
4 3/4	1·000	2·000	3·000	4·000	4·999	5·999	6·999	7·999	9·999	11·999	13·998	15·998	4 3/4
5	1·053	2·105	3·158	4·210	5·263	6·315	7·368	8·420	10·525	12·630	14·735	16·840	5
5 1/4	1·105	2·210	3·315	4·421	5·526	6·631	7·736	8·841	11·051	13·262	15·472	17·682	5 1/4
5 1/2	1·158	2·316	3·473	4·631	5·789	6·947	8·104	9·262	11·578	13·893	16·209	18·524	5 1/2
5 3/4	1·210	2·421	3·631	4·842	6·052	7·262	8·473	9·683	12·104	14·525	16·946	19·366	5 3/4
6	1·263	2·526	3·789	5·052	6·315	7·578	8·841	10·104	12 630	15·156	17·682	20·208	6

Round, Octagonal and Square Steel.—The Weight of a Lineal Foot.

Diameter of Circle and Oct. and Side of Square.	Round in lbs.	Octagonal in lbs.	Square in lbs.
1/8	·0417	·0440	·0532
3-16	·0940	·0991	·1196
1/4	·1670	·1762	·2127
5-16	·2610	·2753	·3323
3/8	·3758	·3964	·4785
7-16	·5115	·5396	·6513
1/2	·6681	·7047	·8507
9-16	·8456	·8919	1·077
5/8	1·044	1·101	1·329
11-16	1·263	1·332	1·608
3/4	1·503	1·586	1·914
13-16	1·764	1·861	2·246
7/8	2·046	2·158	2·605
15-16	2·349	2·478	2·991
1	2·673	2·819	3·403
1 1/8	3·382	3·568	4·307
1 1/4	4·176	4·405	5·317
1 3/8	5·053	5·330	6·433
1 1/2	6·013	6·343	7·656
1 5/8	7·057	7·444	8·985
1 3/4	8·185	8·633	10·421
1 7/8	9·396	9·910	11·963
2	10·690	11·276	13·611
2 1/4	13·530	14·271	17·227
2 1/2	16·703	17·618	21·267
2 3/4	20·211	21·318	25·734
3	24·053	25·371	30·625

Note.—The diameter of Octagon steel is measured across the sides.

Flat Steel.—The Weight of a Lineal Foot.

Width in inches.	Thickness in inches.							
	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/8	·0532	·1063	·1595	·2127	·2658	·3190	·3722	·4253
1/2	·2127	·4253	·6380	8·507	1·063	1·276	1·489	1·701
5/8	·2658	·5317	·7975	1·063	1·329	1·595	1·861	2·127
3/4	·3190	·6380	·9570	1·276	1·595	1·914	2·233	2·552
7/8	·3722	·7443	1·117	1·489	1·861	2·233	2·605	2·977
1	·4253	·8507	1·276	1·701	2·127	2·552	2·976	3·403
1 1/8	·4785	·9570	1·436	1·914	2·393	2·871	3·350	3·828
1 1/4	·5317	1·063	1·595	2·127	2·658	3·190	3·722	4·253
1 3/8	·5849	1·170	1·755	2·339	2·924	3·509	4·094	4·679
1 1/2	·6380	1·276	1·914	2·552	3·190	3·828	4·466	5·104
1 3/4	·7444	1·489	2·233	2·977	3·722	4·466	5·211	5·955
2	·8507	1·701	2·552	3·403	4·253	5·104	5·955	6·806
2 1/4	·9570	1·914	2·871	3·828	4·785	5·742	6·699	7·656
2 1/2	1·063	2·127	3·190	4·253	5·317	6·380	7·444	8·507
2 3/4	1·070	2·339	3·509	4·679	5·849	7·018	8·188	9·358
3	1·276	2·552	3·828	5·104	6·380	7·656	8·932	10·208
3 1/4	1·382	2·765	4·147	5·530	6·912	8·294	9·677	11·059
3 1/2	1·489	2·977	4·466	6·955	7·444	8·932	10·421	11·910
3 3/4	1·595	3·190	4·785	6·380	7·975	9·570	11·165	12·760
4	1·701	3·403	5·104	6·806	8·507	10·208	11·910	13·611
4 1/4	1·808	3·615	5·423	7·231	9·039	10·846	12·654	14·462
4 1/2	1·914	3·828	5·742	7·656	9·570	11·484	12·398	15·313
4 3/4	2·020	4·041	6·061	8·082	10·102	12·122	14·143	16·163
5	2·127	4·254	6·380	8·507	10·634	12·760	14·887	17·014
5 1/2	2·339	4·679	7·018	9·358	11·697	14·037	16·376	18·715
6	2·552	5·104	7·656	10·208	12·761	15·313	17·865	20·417

Copper Bar.—The Weight of a Lineal Foot.

Diam. or Side in inch.	Round in lbs.	Square in lbs.	Diam. or Side.	Round in lbs.	Square in lbs.
1/8	·047	·060	1 1/2	6·811	8·672
3/16	·106	·135	1 9/16	7·390	9·410
1/4	·189	·241	1 5/8	7·993	10·177
5/16	·296	·376	1 3/4	9·270	11·803
3/8	·426	·542	1 7/8	10·642	13·550
7/16	·579	·738	2	12·108	15·417
1/2	·757	·964	2 1/8	13·668	17·404
9/16	·958	1·219	2 1/4	15·325	19·512
5/8	1·182	1·506	2 3/8	17·075	21·740
11/16	1·431	1·822	2 1/2	18·916	24·089
3/4	1·703	2·168	2 5/8	20·856	26·558
13/16	1·998	2·544	2 3/4	22·891	29·146
7/8	2·318	2·951	2 7/8	25·019	31·856
15/16	2·661	3·387	3	27·244	34·688
1	3·027	3·854	3 1/8	29·559	37·638
1 1/16	3·417	4·351	3 1/4	31·972	40·710
1 1/8	3·831	4·878	3 3/8	34·482	43·901
1 3/16	4·269	5·435	3 1/2	37·081	47·214
1 1/4	4·730	6·022	3 5/8	39·777	50·646
1 5/16	5·214	6·634	3 3/4	42·568	54·199
1 3/8	5·723	7·287	3 7/8	45·550	57·873
1 7/16	6·255	7·964	4	48·433	61·667

Strength and Weight of Materials.

Metals.

	Specific Gravity.	Weight of a cubic foot.	Weight of a cubic inch.	Tensile Strength per sq. in.	Crushing Weight per sq. in.	Transverse Strength.
		lbs.	lbs.	tons.	tons.	tons.
Aluminium, sheet	2·67	166·6	·096	—	—	—
„ cast	2·56	159·8	·092	—	—	—
Antimony, cast	6·72	419·5	·242	·47	—	—
Bismuth, cast	9·822	613·1	·353	1·45	—	—
Copper bolts	8·85	552·4	·318	17	—	—
„ cast	8·607	537·3	·31	8·4	—	—
„ sheet	8·78	548·1	·316	13·4	—	—
„ wire	8·9	555	·32	26	—	—
Gold	19·361	1208·5	·697	9·1	—	—
Iron, cast, from...	7	437	·252	6	36	2
„ „ to ...	7·6	474·4	·273	13	64	3·4
„ „ average	7·23	451	·26	7·3	48	2·6
„ wrought from...	7·6	474·4	·273	16	16	3
„ „ to ...	7·8	486·9	·281	29	18	5·5
„ „ average	7·78	485·6	·28	22	16·9	3·8
„ wire	—	—	—	40	—	—
Lead, cast	11·36	708·5	·408	·8	3·1	—
„ sheet	11·4	711·6	·41	1·5	—	—
Mercury	13·596	848·75	·48945	—	—	—
Platinum	21·531	1343·9	·775	—	—	—
„ sheet	23	1435·6	·828	—	—	—
Silver	10·474	653·8	·377	18·2	—	—
Steel	8	499	·288	52	150	—
„ plates	—	—	—	35	90	—
Tin, cast	7·291	455·1	·262	·2·0	6·7	—
Zinc, cast	7	437	·252	3·3	—	—

Strength and Weight of Materials.

Alloys.

	Specific Gravity.	Weight of a cubic foot.	Weight of a cubic inch.	Tensile Strength per sq. in.	Crushing Weight per sq. in.	Transverse Strength.
		lbs.	lbs.	tons.	tons.	tons.
Aluminium bronze, 90 to 95 per cent., copper	7·68	478·4	·276	32	588	—
Bell-metal (small bells) ...	8·05	502·52	·29	1·4	—	—
Brass, cast	8·4	524·37	·3	8	—	—
„ sheet	8·44	526·86	·301	14	—	—
„ wire	8·54	533·109	·307	22	—	—
„ 5 copper, 1 zinc ...	8·41	525·09	·3	13·7	—	—
„ 4 „ 1 „ ...	8·448	527·36	·304	14·7	—	—
„ 3 „ 1 „ ...	8·397	524·18	·3	13·1	—	—
„ 2 „ 1 „ ...	8·299	518·06	·299	12·5	—	—
„ 1 „ 1 „ ...	8·23	513·75	·296	9·2	—	—
„ 1 „ 2 „ ...	8·283	517·06	·298	19·3	—	—
„ 1 „ 4 „ ...	7·371	460·13	·265	1·9	—	—
Gold (standard)	17·724	1106·42	·638	—	—	—
Gun-metal, 10 copper, 1 tin...	8·561	534·42	·308	16·1	—	—
Ditto, 9 tin, 1 copper	8·462	528·24	·304	15·2	—	—
„ 8 „ 1 „	8·459	528·05	·304	17·7	—	—
„ 7 „ 1 „	8·728	544·85	·314	13·6	—	—
Pewter	—	—	—	—	—	—
Silver (standard)	10·312	643·72	·371	—	—	—
Speculum metal	7·447	464·87	·264	3·1	—	—
White metal (Babbett)... ...	·731	456·32	·263	—	—	—

STRENGTH AND WEIGHT OF MATERIALS.

Timber.

		Specific Gravity.	Weight of a cubic foot.	Weight of a cubic in.	Tensile Strength per sq. in.	Crushing Weight per sq. in.	Transverse Strength.
			lbs.	lbs.	lbs.	lbs.	lbs.
Acacia	from	·71	44	·025	16,000	—	1,867
"	to	·79	49	·028	—	—	—
Ash	...	·69	43	·025	12,000	8,600	2,000
"	...	·76	47	·027	17,000	9,300	3,000
Beech	from	·69	43	·025	11,000	7,700	1,500
"	to	·696	43	·025	22,000	9,300	2,000
Birch	...	·711	44	·026	15,000	3,300	1,900
"	...	·730	45	·026	—	6,000	1,930
Box	...	1·28	80	·046	20,000	10,300	2,445
Cedar, West Indian	...	·748	47	·026	5,000	5,700	1,443
" American ...	...	·554	35	·020	—	—	766
" Lebanon ...	...	·486	30	·017	11,000	5,800	1,300
Chestnut	...	·606	38	·022	12,000	—	1,770
Cork	...	·240	15	·008	—	—	—
Deal, Christiana ...	...	·689	43	·025	12,000	5,850	1,562
Ebony	...	1·187	74	·043	—	19,000	2,100
Elm, English ...	...	·553	34	·02	13,200	10,300	782
"	...	·579	36	·021	14,000	—	1,100
" Canadian ...	...	·725	45	·026	—	—	1,920
Fir, spruce	...	·512	32	·018	10,100	6,500	1,490
Hornbeam	...	·76	47	·027	20,000	4,600	—
Iron wood	...	1·15	71	·041	—	—	3,000
Jackwood	...	·67	42	·024	—	—	1,830
Larch	...	·543	34	·019	8,900	3,200	1,330

	Specific Gravity.	Weight of a cubic foot.	Weight of a cubic in.	Tensile Strength per sq. in.	Crushing Strain per sq. in.	Transverse Strength.
		lbs.	lbs.	lbs.	lbs.	lbs.
Larch	·556	35	·02	10,200	5,500	1,660
Lignum vitæ	1·333	83	·048	11,800	10,000	3,440
Lime	·564	35	·02	—	—	—
Mahogany, Nassau ...	·668	42	·024	—	—	1,719
" Honduras ...	·560	35	·02	21,000	8,000	1,910
" Spanish ...	·852	53	·031	—	8,200	1,300
Maple	·675	42	·025	10,600	—	1,694
Oak, African	·988	62	·035	—	—	2,523
" American, red ...	·85	53	·03	10,000	6,000	1,680
" ... white ...	·779	49	·028	—	—	—
" English	·777	48	·028	10,000	6,400	1,600
" "	·934	58	·034	19,000	10,000	1,690
Pine, red	·576	36	·021	12,000	5,400	1,200
" "	·657	41	·024	14,000	7,500	1,530
" white	·432	27	·015	—	—	1,229
" "	·553	34	·02	—	—	—
" yellow	·508	32	·018	—	5,300	1,185
" Dantzic	·649	40	·023	8,000	5,400	1,426
" Memel	·550	34	·02	—	—	1,348
" "	·601	37	·021	—	—	—
" Riga	·466	29	·017	—	—	—
" "	·654	41	·023	14,000	—	1,383
Satinwood	·96	60	·034	—	—	3,200
Teak	·74	46	·026	8,000	12,000	2,110
"	·86	54	·031	15,000	—	—

Jarrah-wood.—In December last, Messrs. T. A. Taylor and Co., merchants and agents, Madras, wrote to the *Chief Engineer for Irrigation, bringing* to his notice the jarrah-wood of Australia, which they were endeavouring to introduce into Madras as a substitute for teak timber, the price for which has advanced so enormously the last few years. With reference to Messrs. Taylor and Co.'s letter, the Acting Chief Engineer for Irrigation now writes:—"Jarrah-wood has already been used for making grilles for the foundation of locks on the Buckingham Canal. It is said to be imperishable under water, but it cracks if exposed to the sun and rain. Its weight is 63lb. a cubic foot, against 46lb., the weight of teak. As the price of teak is now very high, being about Re. 1 a cubic foot more than the price of jarrah in Madras, it seems advisable to make a trial of jarrah for sluice shutters and other irrigation works where it will generally be submerged, and at other times sheltered to some extent from the sun: and it is therefore suggested that the Superintending Engineer, 1st Circle, and the General Superintendent, Public Works Workshops, may be authorised to purchase from Messrs. Taylor and Co. Rs. 500 worth of jarrah timber." The Madras Government approve of the suggestions of the Acting Chief Engineer for Irrigation, and add that after the wood has been fairly tried, a full report on it should be submitted.—*April* 1884.

Strength and Weight of Materials.

Miscellaneous Substances.

	Specific Gravity.	Weight of a cubic foot.	Weight of a cubic inch.	Tensile Strength per sq. in.	Crushing Strain per sq. inch.
		lbs.	lbs.	lbs.	lbs.
Asphalte	2·5	156	·09	—	—
Brick, common ... ... from	1·6	100	·057	—	—
,, ,, ... to	2	125	·072	—	—
,, London Stock	1·84	115	·066	—	—
,, red	2·16	134	·077	—	808
,, Welsh fire	2·4	150	·086	—	—
,, Stourbridge fire	2·2	137	·079	—	1717
Cement, Portland ... ... from	1·3	81	·046	400	3795
,, ,, ... to	1·4	87	·05	600	5984
,, Roman	1·6	100	·057	185	—
Clay	1·9	119	·068	—	—
Coal, anthracite	1·53	95	·055	—	—
,, cannel	1·272	79	·046	—	—
,, Glasgow	1·29	80	·046	—	—
,, Newcastle	1·269	79	·045	—	—
Coke	7·44	46	·026	—	—
Concrete, ordinary	1·9	119	·068	—	—
,, in cement	2·2	137	·079	—	—
Earth ... ... from	1·52	77	·054	—	—
,, ... to	2·00	125	·072	—	—
Glass, flint	3·078	192	·111	2413	27,500
,, crown	2·52	157	·091	2546	31,000

	Specific Gravity.	Weight of a cubic foot.	Weight of a cubic inch.	Tensile Strength per sq. in.	Crushing Strain per sq. in.
		lbs.	lbs.	lbs.	lbs.
Glass, common green	2·528	158	·091	2896	31,876
,, plate	2·76	172	·099	—	—
Gutta-percha	·966	60	·035	—	—
Gypsum	2·286	143	·082	71	—
India-rubber	·93	58	·033	—	—
Ivory	1·82	114	·065	—	—
Lime, quick	·843	53	·03	—	—
Mortar ... ... from	1·38	86	·049	—	—
,, ... to	1·9	119	·068	—	—
,, ... average	1·7	106	·061	—	—
Pitch	1·15	69	·041	—	—
Plumbago	2·267	140	·082	—	—
Sand, quartz	2·75	171	·099	—	—
,, river	1·88	117	·067	—	—
Sand, pit (coarse)	1·61	100	·058	—	—
,, ,, (fine)	1·52	95	·054	—	—
,, (Thames)	1·64	102	·059	—	—
Shingle	1·42	88	·051	—	—
Tallow	·94	59	·034	—	—
Tar	1·016	63	·036	—	—
Tile, common ... ... from	1·81	112	·065	—	—
,, ,, ... to	1·85	115	·066	—	—

Strength and Weight of Materials.

Stones, &c.

	Specific Gravity.	Weight of a cubic foot.	Weight of a cubic inch.	Tensile Strength per sq. in.	Crushing Strain per sq. in.	Transverse Strength.
		lbs	lbs.	lbs.	lbs.	lbs.
Basalt, Scotch	2·95	184	·106	1,469	8,300	—
,, Greenstone	2·9	181	·104	—	17,200	—
,, Welsh	2·75	172	·099	—	16,800	—
Chalk	2·33	145	·084	—	501	—
,, ...	2·62	162	·094	—	—	—
Firestone	1·8	112	·065	—	—	—
Granite, Aberdeen grey	2·62	163	·094	—	10,900	—
,, ,, red	2·62	165	·095	—	—	—
,, Cornish...	2·66	166	·096	—	6,300	—
,, Mount Sorrel	2·67	167	·096	—	12,800	—
Lime stone, Compact	2·58	161	·093	—	7,700	—
,, Purbeck	2·6	162	·093	—	9,160	—
,, Anglesea	—	—	—	—	7,579	—
,, Blue Lias	2·467	154	·089	—	—	—
,, Lithographic	2·6	162	·093	—	—	—
Marble, Statnary	2·718	170	·098	722	3,216	—
,, Italian	2·726	170	·098	—	9,681	—
,, Brabant block	2·697	168	·097	—	9,219	—
,, Dev onshire	—	—	—	—	7,428	—
Oolite, Portland stone	2·423	151	·087	—	4,100	—
,, Bath stone	1·978	123	·072	—	—	—
Sandstone, Arbroath pavement ...	2·477	155	·089	1,261	7,884	—
,, Bramley-Fall	2·5	156	·09	—	6,050	—
,, Caithness	2·638	165	·095	1,054	6,490	857
,, Craglieth	2·45	153	·088	453	5,287	—
,, Derby grit	2·4	150	·086	—	3,100	—
,, Red (Cheshire)	2·15	133	·077	—	2,185	—
,, Yorkshire paving... ...	2·51	157	·09	—	5,714	—
Slate, Anglesea	2·87	179	·103	9,600	10,000	
,, Cornwall	2·51	157	·09	to	to	
,, Welsh	2·88	180	·104	12,800	21,000	1,961
Trap	2·72	170	·098	—	—	—

Lengths and Angles of Slopes.

Slope.	Angle with horizon.	Length (height taken as 1·00).	Slope.	Angle with horizon.	Length (height being 1·00).
¼ to 1	75° 58′	1·0307	1½ to 1	33° 42′	1·802
½ to 1	63 26	1·118	1¾ to 1	29 44	2·016
¾ to 1	53 8	1·25	2 to 1	26 34	2·236
1 to 1	45 0	1·4142	3 to 1	18 26	3·162
1¼ to 1	38 40	1·6	4 to 1	14 2	4·124

Natural Slopes of Earths *(with Horizontal Line.)*

Gravel, average ...	40°	Shingle ...	39°
Dry sand ...	38	Rubble ...	45
Sand ...	22	Clay, well drained ...	45
Vegetable earth ...	28	Do. wet ...	16
Compact earth ...	50		

Tables of the Weights of Materials.

The weight of wrought iron ×	0·928	= cast iron.
„	0·928	= zinc.
„	1·010	= steel.
„	1·082	= brass.
„	1·144	= copper.
„	1·468	= lead.

Weight of Earths, Rocks, &c., per cube yard.

Sand, about	30 cwt.		Sandstone, about	39 cwt.	
Gravel, „	30	„	Shale, „	40	„
Mud, „	25	„	Quartz „	41	„
Marl, „	26	„	Granite, „	42	„
Clay, „	31	„	Trap, „	42	„
Chalk, „	36	„	Slate. „	43	„

Bulk of Rock Earthwork, &c., when placed in Embankment, original Excavation being assumed at 1·00.

Rock, large blocks ...	about	1·50
Medium, unselected	„	1·25 to 1·30
Metal	„	1·20
Chalk	„	1·30
Sand and gravel	„	1·07
Clay and earth after subsidence		1·08
„ „ before „		1·20

Retaining Walls.

E = Weight of earthwork per cube yard.
W = Weight of wall „ „
H = Height of wall.
T = Thickness of wall at top.
T = H × Tabular No.

Batter of Wall.	E : W :: 4 : 5		E : W :: 1 : 1	
	Clay.	Sand.	Clay.	Sand.
1 in 4 ...	·083	·029	·115	·054
1 „ 5 ...	·122	·065	·155	·092
1 „ 6 ...	·149	·092	·183	·118
1 „ 8 ...	·184	·125	·218	·153
1 „ 12 ...	·221	·160	·256	·189
Vertical ...	·300	·239	·336	·267

Portland Cement.

Conclusions derived from Mr. Grant's Experiments.

1. Portland cement improves by age, if kept from moisture.
2. The longer it is in setting the stronger it will be.

3. At the end of a year, 1 of cement to 1 sand is about $\frac{3}{4}$ths the strength of neat cement; 1 to 2 about $\frac{1}{2}$ strength; 1 to 3 about $\frac{1}{3}$rd; 1 to 4, $\frac{1}{4}$th; 1 to 5 about $\frac{1}{6}$th.
4. The cleaner and sharper the sand the greater the strength.
5. Strong cement is heavy; blue grey, slow-setting. Quick-setting cement has generally too much clay in its composition—is brownish and weak.
6. The less water used in *mixing up the cement* the better.
7. Bricks, stones, &c., used with cement should be well soaked.
8. Cement setting under *still* water will be stronger than if kept dry.
9. Blocks of brickwork or concrete should be kept in water until required for use.
10. Salt-water is as good as fresh for mixing cement.
11. Bricks of *neat Portland cement* are *equal* to Blue bricks, Bramley-Fall stone, or Yorkshire landings (in a few months).
12. Bricks of 1 cement to 4 or 5 of sand are equal to picked stock bricks.

Corrugated Iron Roofing.*

$\frac{1}{10}$th of the weight to be added for lappage.

Sheets should overlap about 6 inches, and be double rivetted at joints.

3lbs. of rivets required per square of roofing.

Purlins should be about 6 feet apart.

Curved roofs may be made up to 20 feet span without framing; tie-rods 12 feet apart.

CEMENTS.

Rust Joint.—*(Quick Setting.)*

1 lb. Sal-ammoniac in powder, 2 lbs. Flower of sulphur, 80 lbs. Iron borings. Made to a paste with water.

(*Slow Setting.*)—2 lbs. Sal-ammoniac, 1 lb. of Sulphur, 200 lbs. Iron borings.

The latter cement is best if the joint is not required for immediate use.

For Steam-boilers, Steam-pipes, &c.

Soft.—Red or white lead in oil, 4 parts; Iron borings, 2 to 3 parts.

Hard.—Iron borings and salt water, and a small quantity of Sal-ammoniac with fresh water.

Maltha, or Greek Mastic.

Lime and Sand mixed in the manner of mortar, and made into a proper consistency with milk or size without water.

For China.

Curd of milk, dried and powdered, 10 oz.; Quick-lime, 1 oz.; Camphor, 2 drachms. Mix, and keep in closely-stopped bottles. When used, a portion is to be mixed with a little water into a paste.

For Earthen and Glass Ware.

Heat the article to be mended a little above 212°, then apply a thin coating of gum Shellac upon both surfaces of the broken vessel.

Or, dissolve gum Shellac in alcohol, apply the solution, and bind the parts firmly together until the cement is dry.

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* See page 206.

For Holes in Castings.

Sulphur in powder, 1 part; Sal-ammoniac, 2 parts; powdered iron turnings, 80 parts. Make into a thick paste.

The ingredients composing this cement should be kept separate, and not mixed until required for use.

For Marble.

Plaster of Paris, in a saturated solution of Alum, baked in an oven, and reduced to powder. Mixed with water. It may be mixed with various colors.

For Marble Workers and Coppersmiths.

White of egg, or mixed with finely-sifted Quick-lime, will unite objects which are not submitted to moisture.

Transparent—for Glass.

India-rubber, 1 part in 64 of Chloroform; add gum Mastic in powder, 16 to 24 parts. Digest for two days with frequent shaking.

To Mend Iron Ware.

Sulphur 2 parts, fine Black Lead 1 part. Put the Sulphur in an iron pan, over a fire, until it melts, then add the lead; stir well; then pour out. When cool, break into small pieces. A sufficient quantity of this compound being placed upon the crack of the ware to be mended, can be soldered by an iron.

For Cisterns and Water-casks.

Melted glue, 8 parts; Linseed-oil, 4 parts; boiled into a varnish with litharge.

This cement hardens in about 48 hours, and renders the joints of wooden cisterns and casks air and water tight.

Useful Memoranda for Hydraulic Calculations.

1 Cubic foot of water... = 62·425 lbs. = ·557 cwt. = 0·28 ton.
1 cubic inch... ... ... = ·03612 lbs.
1 gallon... ... ... = 10 lbs. = ·16 cube feet.
1 cube foot of water ... = 6·24 gallons = say $6\frac{1}{4}$ gallons.
1 cwt. of water ... ... = 1·8 cube foot = 11·2 gallons.
1 ton of water ... ... = 35·9 cube feet = 224 gallons.
P = Pressure in lbs. per square inch.
H = Head of water in feet.
V = Theoretical velocity in feet per second.
g = Force of gravity.

$P = H \times \cdot 4335$. $H = P \times 2{\cdot}307$.

Pressure per square foot = H 62·4

$g = 32{\cdot}2$. $2g = 64{\cdot}4$. $\sqrt{2g} = 8{\cdot}025$.

$V = \sqrt{2g\,H} = 8{\cdot}025\sqrt{H}$.

$H = \frac{V^2}{2g} = \cdot 0155\,V^2$. $\frac{1}{2g} = \cdot 0155$.

Sea Water.

1 cube foot of sea water = 64·11 lbs.
Wt. of sea water = 1·027 weight of fresh water.

Rainfall.

Inches of rainfall by 2,323,200 = cube feet per square mile.
Inches of rainfall by $14\frac{1}{2}$ = millions of gallons per square mile.
Inches of rainfall by 3,630 = cube feet per acre.

ENGLISH WEIGHTS AND MEASURES, WITH THEIR RELATIVE VALUES.

MEASURES OF LENGTH.

12	inches			1 foot.
7·92	inches			1 link.
3	feet			1 yard.
$5\frac{1}{2}$	yards	= $16\frac{1}{2}$	feet	1 pole or perch.
100	links	= 22	yards	1 chain = 4 perches.
40	perches	= 220	yards	1 furlong.
8	furlongs	= 1,760	yards	1 mile.
6	feet			1 fathom.
120	fathoms			1 cable's length.
1	Nautical mile			6082 7 feet.
69·12	miles			1 Geographical deg.
3	miles			1 league.

The Irish perch is 21 feet, or seven yards. Three inches make a palm ; 4 inches, a hand ; 5 feet, a pace. In cloth measure, $2\frac{1}{4}$ inches = 1 nail ; 4 nails = 1 quarter ; 4 quarters = 1 yard. 11 Irish miles = 14 English.

MEASURES OF SURFACE.

144	square inches			1 square foot.
62·7264	,,			1 square link.
9	square feet			1 square yard.
$30\frac{1}{4}$	square yards =	$272\frac{1}{4}$	square feet	1 square perch.
10,000	square links =	4,356	,,	1 square chain.
10	square chains =	160	square perches	1 acre.
1	rood =	210	square yards	40 perches.
4	roods =	4,840	,,	1 acre.
640	acres =	3,097,600	,,	*1 square mile.*

The Irish perch is 49 square yards, or 441 square feet ; 1 Irish acre = 1a. 2r. 19·17p. statute ; and 1 statute acre = 0a. 2r. 18·77p. Irish. The Irish acre is to the English acre as 196 is to 121. 100 square feet is a square of roofing, slating, or flooring. The Cunningham acre is = 1a. 1r. 6·61p. English ; and 1 English acre is = 0a. 3r. 3·904p. Cunningham measure.

CUBIC MEASURES, AND MEASURES OF CAPACITY AND WEIGHT.

1,728	cubic inches	1 cubic foot.
27	cubic feet	1 cubic yard.
$16\frac{1}{2} \times 1\frac{1}{2} \times 1$	= 24·75 cubic feet	1 perch of masonry.
$16\frac{1}{2} \times 16\frac{1}{2} \times 1\frac{1}{8}$	= 306 cubic feet	1 rod of brickwork.
$21 \times 1\frac{1}{2} \times 1$	= $30\frac{1}{2}$ cubic feet	1 Irish perch of masonry.

The standard gallon, imperial measure, contains 10 lbs. avoirdupois, of distilled water at 62° Fahrenheit, the barometer standing at 30 inches.

6·232 gallons	1 cubic foot.
8·665 cubic inches	1 gill.
4 gills 34·659 cubic inches	1 pint.
2 pints 69·318 cubic inches	1 quart.
2 quarts 138·637 cubic inches	1 pottle.
2 pottles 277·274 cubic inches	1 gallon.
2 gallons 554·548 cubic inches	1 peck.
4 pecks 2218·191 cubic inches	1 bushel.

Revised Weights and Measures.

The Weights and Measures recognized by Government are as follows :—
(Vide *Fort St. George Gazette*, 20th October 1846.)

Weights.		Avoirdupois. lbs.	oz.	drs.
180 Grains	= 1 Tola	= 0·	0·	6·58
3 Tolas	= 1 Pollum	= 0·	1·	3·75
40 Pollums	= 1 Viss	= 3·	1·	5·94
8 Viss	= 1 Maund	= 24·	10·	15·54

N. B.—1 Dram Avoirdupois = 27·342 Grains.
1 Ounce Avoirdupois = 437½ Grains.

The Company's Rupee weighs exactly 1 Tola.

The Maund is generally spoken of as 25 lbs. Avoirdupois, and the Candy 500 lbs.

Measures.	Cylinder. Diam. In.	Depth. In.	Contents in cubic inches.	Weight of water at 80° Fahr.* (Avoirdupois.) lbs.	oz.	drs	grs.
1 Olluck.	2·6	2·4	12½	0·	7·	3·	6
8 Ollucks = 1 Measure.	5·0	5·1	100	3·	9·	9·	20
4 Ollucks = ½ Measure.	4·0	4·0	50	1·	12·	12·	23
2 Ollucks = ¼ Measure.	3·2	3·1	25	0·	14·	6·	12
8 Measures = 1 Mercal.	10·3	9·6	800	28·	12·	13·	22
4 Measures = ½ Mercal.	8·2	7·6	400	14·	6·	6·	24

The Parah of 5 Mercals (used for Chunam, &c.) is a square measure, the sides 20 inches and depth 10, containing 4,000 cubic inches. The old Parah was 24 X 24 X 6½=3,744 cubic inches.

The "Garce" is 400 Mercals or 185·2 cubic feet, or 5·152 Tons of water. According to the *old* Measure of Madras, the Puddee or "Measure" was 93¾ cubic inches, and the Mercal 750 cubic inches.

The Standard Madras Puddee or "Measure" is generally a Cylinder 4 inches in diameter and 8 inches deep, containing 100 cubic inches, as in the above Table. Now 100 cubic inches of *water* at 80° weigh 3·6 lbs. Avoirdupois, *or* 140 *Tolas exactly*.

1 Measure	...	= 1·44	Quarts.
2·77 Measures	...	= 1	Gallon.
22·18 Measures	...	= 1	Bushel.

22·18 Mercals	... = 1 Quarter.	
177½ Measures	... = 1 Quarter.	
1 Garce	... = 18 Quarters.	

The "Seer" is often spoken of as a *measure*, whereas it is properly a *weight* of 80 Rupees, (though in some places it is 84 Rupees). Where the Seer is spoken of as a measure, it is usual to calculate 2 Madras Measures to 3 Seers, and it so happens that 2 of the Madras Regulation Measures contain about 6·2 lbs. of *paddy*, a weight equal to 3 Seers of 80 Rupees, 1 lb. Avoir. = 38·889 Tolas.

Measures and Weights in the Teloogoo Country.

Capacity.

4 Giddas ... ... 1 Sola.	4 Coonchums... ... 1 Toom.
4 Solas... ... ... 1 Manika.	20 Tooms ... ... 1 Pooty.
4 Manikas ... ... 1 Coonchum.	

Weight.

3 Tolas... ... ... 1 Pullum.	5 Seers ... ... 1 Viss.
2 Pullums ... ... 1 Pow-seer.	8 Viss ... ... 1 Munoogoo.
4 Pow-seers... ... ... 1 Seer.	20 Munoogoos or Maunds 1 Barum or Candy.

Long Measure.

9 Unglums or Inches 1 Chénoo (or span).	2 Gugs ... ... 1 Bāra (or fathom.)
12 Unglums... ... 1 Udagoo (or foot).	2 Bāras ... ... 1 Tundamoo.
2 Chénoos ... ... 1 Moora (or cubit).	1000 Tundamoos ... 1 Coss (2¼ miles.)
2 Mooras ... ... 1 Gug (or yard).	4 Coss ... ... 1 Gow (10 miles.)

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* Barometer at 30·0

Sp. Gravity			lbs. Avoir.
Water at 80° ·9983	at 80° a cubic foot of water	=	62·215
85° ·9977	85°	=	62·175
62° 1·0000	62°	=	62·32

In England the Standard temperature used is 62.

Nellore.

1 Seer	=	about 65 cubic inches.
3½ Seers	=	1 Moontah or 2½ Madras Regulation Measures.
4 Moontahs	=	1 Cooncha.
4 Coonchas	=	1 Toom or Pooty or Candy of about 747 Madras Measures.

N.B.—The Mankay is also in common use, being of a capacity of about 121 cubic *inches. It is sometimes* called Puddee, though the Madras Puddee or Measure is in Woodiagherry known as the Tuvva. The *seer* is a measure that holds when heaped, 80 Tolas weight of *rice*.

Ganjam.

2 Guddaloos	... 1 Arasola.	4 Uddas ...	... 1 Toom.
2 Arasolas	... 1 Sola.	4 Tooms ...	... 1 Nuvvaty (1000 Arcot Rs.)
2 Solas	... 1 Tuvva.		
2 Tuvvas	... 1 Udda.	20 Nuvvaties	... 1 Burnum.

Madras Long Measure.

About 8 English Inches	*one span.*
About 18 do do.	one cubit.
About 1½ mile	one Malabar mile.*
7 Malabar miles about 10 Statute miles	one gno or kādum.
About 2 Malabar miles	one koss or kuroo.†

8 torahs‡	1 vurral	1 1-6th inches.	
24 vurrul	1 Molakole	28th do.	Used in Malabar.
4 molakole	1 dunnoo	3 yads 4 inches.	Used in Malabar.
2,000 dunnoo	1 koeda	6,222 2 9th yards.	Used in Malabar.
4 koeda	1 kādum	24,888 8-9th do.	Used in Malabar.
9 ungul	1 jenoo	or span.	Used in Canara and in Telingana.
12 do.	1 heji	or foot.	Used in Canara and in Telingana.
18 do.	1 mola	or cubit.	Used in Canara and in Telingana.
3 heji	1 gozoo	or yard.	Used in Canara and in Telingana.
2 gozoo	1 maroo	or fathom.	Used in Canara and in Telingana.
2,000 maroo	1 hurudari	or koss.	Used in Canara and in Telingana.

Tinnevelly kole	20½	English	feet	Used in measuring irrigated land.
Madura kole	24	do.	do.	Used in measuring irrigated land.
Tinnevelly chain	398	do.	do.	Used for dry Grain lands.
Madura do.	160	do.	do.	Used for dry Grain lands.
Do. poonjakole	5	do.	do.	Used for dry Grain lands.
Coimbatore chain	102	do.	do.	Used for dry Grain lands.
Do. *mercal.*	6 3-8th	do.	do.	Used for dry Grain lands.
Guntoor chain / Masulipatam do.	33	do.	do	
Nellore puggum	52	do.	do.	

Madras Land Measure.

1 Munnee or Ground (60 feet × 40 feet) = 2,400 square feet.
24 Grounds .... 57,600 square feet or 1 Cawnie,

or

1 Kole or Rod .... = 24 feet.
1 square Kole or Goolee .... = 576 square feet.
100 Goolees .... = 57,600 square feet or 1 Cawnie.

In some districts the Cawnie is divided into Annas or sixteenths, each Anna being 3,600 square feet or a square of 60 feet each way.

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* *This is the distance that would be walked in an average ghurri of 24 minutes at the rate of* 3¾ English miles per hour.

† According to Reynell, the koss in road measure is about 1 9-10th of an English statute mile. *Distances to be laid down in maps may be calculated.*

In Malwa	35	Koss	1 degree.
Between Buglana and Masulipatam	46	do	1 do.
In the Carnatic	35¼	do	1 do.
In Hindoostan	43¾	do	1 do.
In Mundla, Nagpoor, and Bundlecund	22	Goondy do	1 do.

The Emperor Akbar's Koss about 2 1-16th English miles.

In India, *direct distances are shorter than winding roads* intersected by water-courses by 1 part in 7; in flat country with few obstacles, for short distances by 1 part in 10; for distances of 100 to 150 miles by 1 part in 8; for distances of 200 to 300 miles, by 1 part in 7; in the Carnatic, for distances of 100 miles, by 1 part in 9; in England, for distances of 100 miles, by 1 part in 11.

‡ A torah is the breadth of the seed called "yevan" (poppy ?)

The Goolee is often called Coolee or Goontah.

Since an Acre is 43,560 square feet or 4,840 square yards.

And a Cawnie is 57,600 square feet or 6,400 square yards it follows that

1 Cawnie.................................... = 1·322,316 Acres.

1 Acre.. = 0· 75,625 Cawnies.

And 640 Acres or 484 Cawnies .... = 1 square mile.

In Salem, Bellary, Cuddapah and the Palnād Division of Guntoor, the English Acre is used; it is divided into 40 Goontahs, each Goontah being a square of 33 feet each way.

In North Arcot, South Arcot and Chingleput, the Cawnie is used.

The Cawnie is also used in the measurement of *Wet* Land in Coimbatore, Trichinopoly, and the Madura Division of Madura.

In Tanjore the measurements are in Vaylies, each Vaylie being divided into 20 Mows, and each Mow into 100 Goontahs or Goolies of 144 square feet.

A Vaylie is exactly 5 Cawnies or $6\frac{6}{10}$ Acres, or 288,000 square feet.

In the following Districts other Measurements are used.

Districts.	Land, &c.	Name of Measures.	Square Feet.	Acres.
Tinnevelly	Dry Land	Chain	1,58,404	3·64
	Wet do.	Seedcottah*......	70,602	1·62
Madura	Dry do.	Goolee	25,030	·588
Dindigul	Wet and Dry	Do.	,,	,,
Coimbatore........	Dry Land	Bullah	1,66,464	3·83
Trichinopoly......	In the Dry Talooks	Dry Cawnie ...	44,100	1·01
Nellore	Wet and Dry	Goortoo	1,35,200	3·125
Masulipatam......	Do. do.	Cutty†	6,63,552	15·2
Rajahmundry.....	Do. do.	Candy‡	2,30,400	5·3

Measurement of Areas.

Triangle................ $= \frac{\text{Base} \times \text{Perp.}}{2}$

or if Equilateral .... = square of any side × ·433.

Trapezoid....

$= \frac{2 \text{ Parallel sides}}{2} \times$ Perpendicular distance between them.

Trapezium ..

= Diagonal × ½ sum of Perpendiculars.

Circle............... = $\text{Diameter}^2 \times ·7854$, or $\text{Circumference}^2 \times ·0796$.

Parabola .... = ⅔ds of the base × alt.

Ellipse .... = [transv. axis × cong. axis] × ·7854.

Measurement of Surfaces.

Prism .... = (Perimeter of one end × length) + Areas of the two ends.

Sphere .... = $\text{Diameter}^2 \times 3·1416$

Cone .... $= \frac{\text{(Perimeter of Base}}{2} \times$ slant height) + Area of Base.

Cubic Contents.

Prism .... = (Area of Base) × Height.

Cylinder............ = (Area of Base) × Height.

Cone .... = (Area of Base) $\times \frac{\text{Height}}{3}$

Sphere .... = $\text{Diameter}^3 \times ·5236$ or $\text{Circumference}^3 \times ·0169$

* Divided into 168 Puddees. It is supposed to require 1 Cottah or Kotay (21 Tinnevelly Mercals) of Seed

† Divided into 32 Goontahs. ‡ Divided into 100 Goontahs.

To find the Area of Triangle whose Perpendicular is not known.

Call the 3 sides a, b, and c; and ½ their sum call S; then the Area $=\sqrt{(S-a)\times(S-b)\times(S-c)\times S}$.
N. B.—This is easily worked out by Logarithms.

To find the Area of a long irregular Figure, in Land Surveying.

Take *any* number of offsets at *equal* distances along E. D. Add all the offsets together: divide the sum by the number of offsets plus 1, and multiply the Quotient by E. D.

The Ordnance Survey of Great Britain is laid down on a scale of 6 inches to a mile. *The scale of the "Indian Atlas" in sheets, is 4 miles to 1 inch. Areas of Fields* cannot well be computed in a Map whose scale is less than 5 Gunter's chains to an inch, or 16 inches to a mile. The scale used in the Bombay Revenue Survey, and also in the N. W. Provinces, is 4 inches to the mile.

Plans and Sections for projected Railways are required to be drawn on Scales not less than 4 inches to 1 mile for the Plan and 100 feet to the inch Section.

An angle of 7° or 8° is the greatest ascent that a carriage can surmount: 13° for beasts of burden: an angle of 35° cannot be ascended by a man, without steps, and with steps 45° is very difficult. Holborn Hill is 1 in 18, or 3¼ degrees.

THE AVERAGE FALL OF RAIN AT MADRAS.

	Inches.
January	1·19
February ...	·17
March.........	·61
April	·40
May............	1·08
June	1·46
July...........	3·73
August	4·76
September...	4·30
October	11·12
November ...	15·13
December ...	4·61
	48·56

On the 21st October 1846, *there fell 17 inches in 12* hours; and 3¾ inches the previous 12 hours. Flooding the whole country.

The fall of rain in a continuous downpour during the Monsoon is about 3½ inches in 12 hours.

The strength of a mild sea breeze is about ½ lb. on a square foot. Fresh sea breeze ¾ lb. A gale of wind such as the Cape hard South Easters press about 8 lbs. *on the* square foot, with gusts of 20 lbs. The English channel severe Winter gales about 10 lbs. with *occasional* heavy gusts of 24 lbs.

During the Hurricane at Madras in November 1846, the pressure at one time was calculated to have been 57 lbs.! on the square foot.

Table of Monthly and Yearly Results of the Observations of the Rain Gauge at the Madras Observatory, from 1804 to 1807, and from 1813 to 1858.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1804	..	1·050	0·032	..	..	0·992	0·747	3·167	1·525	12·410	5·925	5·260	31·108
1805	2·385	..	..	..	0·340	1·395	2·665	3·400	3·420	6·460	6·160	4·990	31·215
1806	0·430	..	..	..	..	..	3·350	14·232	1·550	30·900	7·300	3·700	61·462
1807	..	..	..	0·075	1·700	..	1·381	1·050	2·230	5·785	..	42·000	54·221
1813	..	..	0·425	..	0·275	2·700	1·275	0·825	2·325	5·100	28·750	3·975	45·650
1814	..	..	...	..	..	..	1·600	4·825	8·450	7·100	6·600	3·700	32·275
1815	1·650	..	..	..	..	..	6·475	..	2·850	6·250	33·175	4·800	55·200
1816	0·100	0·725	..	..	0·200	0·450	4·625	3·875	9·500	6·825	12·325	1·450	40·075
1817	0·350	..	..	..	0·175	0·175	1·775	3·475	7·700	19·500	24·325	6·250	63·725
1818	..	..	..	0·600	..	0·750	12·650	6·400	5·400	17·900	25·600	7·780	77·080
1819	..	..	..	2·500	..	0·125	3·300	1·300	5·900	3·000	10·800	0·700	27·625
1820	..	..	6·750	0·500	17·170	0·850	3·520	3·170	1·700	12·280	4·500	19·700	70·140
1821	3·600	..	0·320	1·700	..	1·100	1·200	3·170	7·300	13·020	11·350	4·850	47·110
1822	1·870	..	...	0·620	..	1·770	0·550	6·700	2·370	20·570	21·370	3·270	59·090
1823	1·450	..	0·920	..	0·270	2·050	2·870	3·150	4·400	10·400	0·900	0·200	26·610
1824	1·270	..	..	..	0·050	0·450	0·250	2·650	0·470	14·250	10·270	3·950	33·610
1825	0·170	..	..	..	4·250	1·500	3·070	7·670	3·500	15·700	9·960	7·350	53·170
1826	..	..	..	..	1·050	8·520	2·100	9·570	2·100	0·820	26·040	11·050	61·250
1827	8·600	0·070	..	..	23·300	3·020	4·900	2·520	4·440	13·710	22·120	5·980	88·660
1828	1·620	..	4·310	0·720	0·400	0·130	3·370	7·300	5·720	9·200	2·610	2·460	37·840
1829	0·270	3·160	0·890	0·050	1·420	2·750	1·520	2·940	2·990	6·150	8·990	5·490	36·620
1830	..	..	0·200	0·310	0·290	2·890	7·200	2·730	4·270	6·220	3·870	4·450	82·430
1831	0·040	..	0·170	..	0·940	3·900	3·130	9·500	7·200	9·350	7·930	2·190	44·350
1832	..	0·100	..	..	0·630	0·510	1·550	2·260	7·710	5·280	0·410	..	18·450
1833	0·180	..	..	..	0·330	1·460	1·070	7·110	3·930	9·690	9·970	3·270	37·010
1834	0·060	..	..	3·650	0·200	2·430	7·080	4·100	4·870	8·010	7·320	1·290	39·010
1835	0·060	..	..	3·370	1·750	0·730	5·310	3·010	3·260	11·170	10·960	1·570	41·190
1836	..	0·320	0·150	..	..	0·500	6·680	9·000	1·140	8·510	18·640	2·020	46·960
1837	..	..	..	2·230	2·560	0·110	2·650	1·690	3·800	13·790	17·170	3·190	47·190
1838	..	1·330	0·590	0·770	0·540	0·880	2·370	4·690	8·780	6·270	21·890	4·220	52·330
1839	3·340	..	..	1·620	0·990	2·460	4·610	6·830	11·140	0·990	21·270	..	53·250
1840	..	..	..	0·030	..	0·480	4·360	7·820	8·360	10·160	27·250	0·120	58·580
1841	1·990	..	..	0·470	4·540	5·030	1·330	8·530	4·310	27·380	6·130	1·310	61·020
1842	1·780	..	0·040	..	0·310	1·310	3·170	3·180	5·650	7·820	12·870	0·160	36·290
1843	6·610	..	0·690	..	14·160	1·880	1·350	2·360	4·250	6·370	5·280	7·930	50·880
1844	0·674	0·495	..	..	2·703	2·661	3·217	2·657	12·420	13·503	3·669	23·229	65·228
1845	1·512	..	0·020	0·043	1·512	2·359	2·901	2·014	4·095	3·363	5·119	15·325	38·263
1846	2·938	0·228	..	..	1·344	3·706	9·121	5·343	0·922	30·586	19·391	6·896	80·475
1847	0·002	0·217	..	0·454	0·725	3·792	3·092	9·712	5·869	16·314	18·662	22·155	80·994
1848	..	..	..	6·377	0·100	1·857	3·869	5·126	3·092	13·933	17·285	3·112	54·751
1849	2·504	..	..	1·123	0·035	3·901	3·580	4·886	1·648	9·191	6·141	6·806	39·815
1850	0·043	4·270	..	0·980	2·939	2·920	1·527	3·058	3·041	4·320	8·121	5·662	36·881
1851	..	..	..	..	18·603	1·261	6·496	4·338	1·700	5·629	24·846	1·446	64·319
1852	..	..	2·623	..	2·224	1·886	7·995	2·263	6·778	20·601	19·402	8·920	72·692
1853	2·248	..	3·367	0·772	..	0·622	4·135	1·377	2·229	9·071	11·993	..	35·814
1854	0·425	0·295	0·089	..	..	1·147	4·295	7·054	6·366	10·221	9·286	4·021	43·199
1855	0·939	0·676	0·260	0·071	..	1·116	2·684	1·646	3·753	10·619	1·472	9·088	32·324
1856	..	0·028	..	0·006	5·508	0·818	3·321	5·677	1·059	3·884	16·974	9·713	46·988
1857	0·323	..	0·099	0·123	0·067	2·931	2·392	0·924	1·550	37·726	5·820	0·995	52·950
1858	..	0·020	..	0·832	3·034	1·633	3·083	2·109	3·607	12·071	22·119	..	48·508
Sums of 50 years.	49·433	12·984	21·945	29·996	116·634	85·907	176·761	222·383	222·639	569·372	640·330	297·493	2445·877
Average.	0·989	0·260	0·439	0·600	2·333	1·718	3·535	4·448	4·453	11·387	12·806	5·950	48·918

GLOSSARY OF INDIAN TERMS IN USE IN THE DEPARTMENT OF PUBLIC WORKS.

Abkarry................The revenue derived from spirituous and fermented liquors.
Achecut................A shallow tank, the bed of which is cultivated. Applies also to lands cultivated as wet, by rainfall purely, the beds being banked high to retain the water.
Agrahrum...............A village inhabited by Brahmins.
Allum..................Salt pans.
Amani..................Lands, (or other sources of revenue,) held under the immediate management of Government Officers, and not leased or rented out; in contradistinction to Zemindary. Also lands where the Government share is received in kind, in contradistinction to a money rent.
Ameen..................A subordinate collector of revenue.
Amildar................A native collector of revenue.
Anna...................A sixteenth of anything.
Annicut................A masonry or earthen dam across a river.
Ayacut.................The whole extent of the lands of a village.
Baghayet...............Land on which garden products (as chillies, tobacco, turmeric, &c.,) are raised.
Batta..................Extra or daily allowance to servants, peons, &c.
Bazaar.................A market place.
Bediga.................Quit-rent.
Beegah.................A measure of land varying in extent in different parts of India.
Bériz..................Rent, revenue.
Bheasty................A water-bearer.
Bund...................The artificial bank of a tank.
Burkundauz.............A peon armed with a matchlock.
Cadjan.................The leaf of the Palmyra tree used for writing accounts, letters, &c., on with an iron pen.
Cadarumbum.............Dry or waste lands.
Calingulah.............A masonry work in the bank of a tank or channel, to allow surplus water to flow freely off.
Calwah.................An artificial irrigating channel.
Canama.................Pass across hills, generally hitherto applied to the foot and cattle tracks.
Cawny..................6,400 square yards, or 1·32 acres. In the town of Madras it is divided into 24 grounds, or Maunies. In the provinces it is divided into 100 Coolies or Goolies, or into sixteenths called annas. The anna being a square of 60 feet each way.
Chumba.................The name of one of the rice crops in Southern India.
Chunam.................Lime. Lime plaster.
Chuprasse..............A messenger or courier wearing a badge as a mark of office, usually a public servant.
Chuttrum...............A rest-house for travellers.
Circar.................The State or Government.
Colum..................A tank.
Conicopoly.............An Accountant, the village accountant.
Cooly..................Hire—wages. A hired laborer, or porter.
Corumboo...............A temporary dam of mud or sand and grass stretching obliquely across a river.
Cotaur.................A depôt for the sale of sea salt.

Covil....................A temple.
Cowle....................A lease or grant.
Cuddoopoocar.........The name of one of the rice crops in Southern India.
Curnum...................A village accountant.
Cusbah...................The place where the tahsildar holds his cutcherry.
Cutcherry...............A revenue office—place where public business is transacted.
Cuttoo badi enam....Lands given to the *cuttoo badi*, or ancient militia of the country, in remuneration for services.
Cutwal...................A native superintendent of police.
Darogah.................A manager or superintendent of any department.
Deloyet..................A peon who attends on the Collector.
Devastanum............Belonging to a Hindoo temple.
Dindoos..................Large stones, above a cubic yard in content, used in river works.
Dittum....................Fixed—the extent of land taken up by the ryots in the aggregate at the commencement of the year.
Duffadar................A head Peon. A native officer of irregular horse, under Jamadar.
Durkhast ....A proposal, a bid for occupying waste lands for cultivation.
Duswundum ....An assignment of land, or rent, given as a compensation for the construction of a tank, &c.
Enam ....Gift or grant.
Fusly ....Revenue year commencing 12th of July. Fusly 1262 extends from July 1852 to July 1853.
Gingelly ....The term applied to the oil extracted from the seed called *Yellow* or *Noovaloo* (Sessanum Orientale.)
Gollah ....Peons, exclusively employed in the Treasury.
Golundauze ....A Native Artilleryman.
Gomastah ....A clerk or agent.
Gowdah ....Head of a village.
Gramum................Village—*gramutar*, villager.
Gunny ....Coarse cloth used for bags—it is made from the fibres of cocoanut, bamboo, &c.
Hookum namah ...Standing rules.
Hoozoor ....The office of the head of a department.
Hungamy ....Temporary, extra.
Jaggery ....Sugar in its unrefined state.
Jaghire ....An assignment to an individual of a portion of territory; generally as a reward for Military service.
Jamadar................The chief or leader of any number of persons; in Military language a native subaltern officer, second to the Subadar.
Jameen ....A village or villages held in rental or contract for a lump sum, irrespective of out-turn or assessment.
Jummabundy ......Settlement of revenue.
Jungar ....A ferry boat.
Jurreeb ....Measurement of lands.
Karkhana ....An office or place where business is carried on; a workshop, a manufactory, an arsenal.
Kist.......................An instalment—the word applies generally to the fixed instalments for paying revenue.
Kooshky ....Dryness, drought; dry land, land not artificially irrigated by land in opposition to by water, as travelling.
Kudimaramut ......Repairs of the channels of irrigation on the borders of the fields by the cultivators themselves.
Lascar...................A native sailor, but especially applied also to tent-pitchers, inferior artillerymen, and others.
Lungurkhana ......A charitable institution for the relief of sick and indigent persons.
Lunka...................The berm or space between the roadway, and the side channel—also the space between a river or channel bank, and its margin.
Mahsool ....The actual crop produced—actual collection.
Maistry ....A master-bricklayer, carpenter, smith, &c. A superintendent of building works.

Maramut ....Repairs.
Maumool ....Established custom—usual.
Maund ....A weight of 28$\frac{3}{7}$lbs. avoirdupois in Bengal, and 25lbs. at Madras. The Indian maund is 822lbs.
Maunium ....Gift or grant of land, to village servants for service, or for service rendered. These lands are not assessed generally.
Merassee ....A species of landed tenure involving a proprietary right to land in occupation and other privileges.
Merassidar ....The holder of the *merassee*.
Metta ....High and dry land, not capable of irrigation, but depending on the rain, and, therefore, unfit for rice.
Modussil ....A screen formed with bamboos and cocoanut, or palmyra, leaves for the protection of the banks of rivers from the action of the stream.
Mofussil ....Properly separate, distinct, particular; in *Hindustan*, a subordinate or separate district; the country, the provinces, or the stations in the country, as opposed to the *Sadar*, or principal station or town.
Monigar ....The head village officer in the revenue department.
Moodam ....A village servant corresponding with Taliar of the Tamil Districts.
Moonsif ....Head police officer of a village.
Mootah ....The sub-division of a talook—a small permanently assessed estate.
Mootsuddy ....A clerk; an accountant.
Mosque ....A Mahomedan place of worship.
Moturpha ....A tax on the profits of trade, or on artizans.
Naib ....A deputy.
Neer kuttee ...... / *Neerauneekauren* } One who distributes water to the fields.
Neer pyre ....Wet cultivation.
Niruck namah ......Price Current—a tarif list of the prices of articles.
Nunjah ....Irrigated land. *Maganee* is the corresponding term in Teloogoo Districts.
Oopenaur ....A river or channel communicating with and opening to the sea.
Oopur ....A class of tank-diggers, who engage principally in earthworks.
Pagoda ....The European designation of a Hindu temple in the south of India; also the gold coin formerly coined at Madras.
Peon ....A messenger, generally on the public service.
Peramboke ....Waste land.
Peshanum ....A species of fine rice.
Peshkar ....A subordinate revenue and police officer under the Tahsildar.
Peshkush ....Fixed assessment on Zemindaries and Mootahs.
Pettah ....The suburbs of a fortified town.
Picotta ....A machine for raising water, consisting of a balance lever with a weight at one end and a vertical rod and bucket at the other, worked by a man walking on the lever.
Poliput ....Villages or districts belonging to a Poligar.
Poonjah ....Dry grain land.
Potail ....Head of the village.
Puckally ....A large leather bag for carrying water in, usually double, thrown over a bullock: also a leather bag used for raising water from wells: a water carrier.
Puddoogay ....The space between the margin of a river or channel and the artificial bank.
Punchayet ....An assembly or jury of five.
Purganah ....A talook province or division.
Putta ....A deed given (usually each year) to ryots to show the amount payable to Government on account of their lands.
Pygust ....An overseer.
Pymash ....Measurement of lands—survey.
Raggy ....A kind of grain,—also called *Natcheny*.

Razeenamah ....An agreement or acquittal of anything.
Ryot ....Villager or cultivator.
Saderwared ....Incidental charges.
Sagoobadi ....Cultivation.
Seycal ....Land constantly under cultivation. Cultivable land.
Sayer ....Land customs.
Shandy ....A market, a fair, an annual fair.
Sheristadar ....Head native officer of a Collector's cutcherry.
Shist ....Assessment of land.
Shroff ....An examiner and sorter of coins. A money-changer.
Shrotrium ....A village held at a favorable assessment.
Shrotriumdar ......The holder of a shrotrium village.
Sibbundee ....An establishment of peons—revenue servants.
Sunnud ....A patent, or written authority from the Ruling power to hold land or office.
Tahsildar ....A native revenue officer who has the management of a talook.
Tak ....A piece of land surveyed and assessed.
Takeed ....An order, a letter of instructions.
Taliar ....A watchman of a village.
Talook ....Every district is divided into portions called *talooks*, each of which has its own establishment for Revenue, Police and Public Works.
Tangal ....A small tank.
Tannah ....The station of a police guard.
Tappal ....The post: the carriage and delivery of letters, &c.
Tariff ....Determination, ascertainment, a table of rates of export and import duties.
Teerwah ....Money assessment or rent.
Thookoodee ....Same as *talook*.
Tolacut ....A revetment to a river or channel bank, where picottahs are fixed for raising the water.
Tope ....A grove of trees, properly of those that bear fruit, as mango, tamarind, cocoanut, &c.
Toty ....An inferior village servant employed for various purposes.
Tumbogy ....A portion of an annicut made lower than the rest (with or without dam stones at intervals) and which can be raised to the height of the rest with earth and turfs.
Urzee ....A petition.
Vakeel ....One endowed with authority to act for another. An Ambassador, an agent. An authorized Attorney. A Pleader in a Court of Justice.
Voycal ....Same as *calwah*.
Waughany ....A jetty run out from the bank of a river in order to turn the stream from it.
Wudder ....A tank-digger.
Wussool ....Collections—net circar demand upon land.
Yairy ....A tank.
Zemindar ....A holder of an estate.
Zillah ....A district or collectorate.